AD-A100 472   ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS   F/G 13/2
BEACH NOURISHMENT TECHNIQUES. REPORT 4. WAVE CLIMATES FOR SELEC--ETC(U)
APR 81 D L DURHAM, L Z HALES, T W RICHARDSON
UNCLASSIFIED   WES-TR-H-76-13-4   NL

END
DATE
FILMED
7 81
DTIC

TECHNICAL REPORT [illegible]

BEACH NOURISHMENT TECHNIQUES

Report [illegible]

WAVE CLIMATES FOR SELECTED U. S. OFFSHORE BEACH NOURISHMENT PROJECTS

MAIN TEXT

by

Donald L. Durham, Lyndell Z. Hales, Thomas W. Richardson

Hydraulics Laboratory
U. S. Army Engineer Waterways Experiment Station
P. O. Box 631, Vicksburg, Miss. 39180

April 1981

Report 4 of a Series

Prepared for Office, Chief of Engineers, U. S. Army
Washington, D. C. 20314

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER: Technical Report H-76-13	2. GOVT ACCESSION NO.: AD-A100 472
3. RECIPIENT'S CATALOG NUMBER	
4. TITLE (and Subtitle): BEACH NOURISHMENT TECHNIQUES. REPORT 4, WAVE CLIMATES FOR SELECTED U. S. OFFSHORE BEACH NOURISHMENT PROJECTS. Main Text.	5. TYPE OF REPORT & PERIOD COVERED: Report 4 of a series
	6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s): Donald L. Durham, Lyndell Z. Hales, Thomas W. Richardson	8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS: U. S. Army Engineer Waterways Experiment Station, Hydraulics Laboratory, P. O. Box 631, Vicksburg, Miss. 39180	10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS: Office, Chief of Engineers, U. S. Army, Washington, D. C. 20314	12. REPORT DATE: April 1981
	13. NUMBER OF PAGES: 56
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)	15. SECURITY CLASS. (of this report): Unclassified
	15a. DECLASSIFICATION/DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

A limited number of copies of Appendixes A through K were published under separate cover. Copies of this report and the appendixes are available from National Technical Information Service, Springfield, Va. 22161.

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

Beach nourishment
Dredging
Deep water waves
Water wave characteristics
Water wave measurement

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Data are presented describing the average wave climate at 10 selected beach nourishment sites on the coastline of the continental United States: Revere Beach, Mass.; Rockaway Beach, N. Y.; Carolina Beach, N. C.; Nassau County, Fla.; Dade County, Fla.; Treasure Island, Fla.; Panama City, Fla.; Redondo Beach, Calif.; Indiana Dunes, Ind.; and Presque Isle, Pa. The data were derived by calculating the effects of refraction, shoaling, and island

(Continued)

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

Unclassified

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

20. ABSTRACT (Continued).

-sheltering on the deepwater wave climate applicable to each site. Deepwater wave climates were obtained from Svnoptic Shipboard Meterological Observation data tapes and California Department of Navigation and Ocean Development Files. Tables and plots of wave height/period frequency distribution on a monthly, annual, and azimuth of approach basis are presented as a means of summarizing the calculated data. The intent of this report is to provide information that can be used later to evaluate the ability of various offshore dredging systems to perform beach nourishment work.

PREFACE

The study reported herein was conducted under the auspices of the Beach Nourishment Techniques project using funds authorized by the Operations Division, Office, Chief of Engineers (OCE), through the Investigation of Operations and Maintenance Techniques research program.

The study was conducted in the Hydraulics Laboratory of the U. S. Army Engineer Waterways Experiment Station under the general supervision of Mr. H. B. Simmons, Chief of the Hydraulics Laboratory; Mr. F. A. Herrmann, Jr., Assistant Chief of the Hydraulics Laboratory; Dr. R. W. Whalin, Chief of the Wave Dynamics Division; Mr. R. A. Sager, Chief of the Estuaries Division; Mr. E. C. McNair, Jr., Chief of the Research Projects Group; and Mr. T. W. Richardson, Research Hydraulic Engineer, Estuaries Division.

The work described herein was accomplished by Drs. D. L. Durham, Research Oceanographer, and L. Z. Hales, Research Hydraulic Engineer, Wave Dynamics Division. This report was prepared by Mr. Richardson and Dr. Hales. Special acknowledgment is made to Mrs. R. M. Brooks, mathematician, Wave Dynamics Division, for her extensive work in data retrieval, and Mr. K. A. Turner, Computer Specialist, Wave Dynamics Division.

Directors of WES during the study and the preparation and publication of this report were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Technical Director was Mr. F. R. Brown.

CONTENTS

* A limited number of copies of Appendixes A through K were published under separate cover. Copies are available from National Technical Information Service, Springfield, Va. 22161.

BEACH NOURISHMENT TECHNIQUES

WAVE CLIMATES FOR SELECTED U. S. OFFSHORE BEACH NOURISHMENT PROJECTS

PART I: INTRODUCTION

1. This report is one of three reports in the Beach Nourishment Techniques series aimed at quantifying the engineering characteristics of beach nourishment projects and representing the range of conditions encountered in the continental United States. Particular emphasis is placed on those projects where offshore sand borrow sources appear necessary and/or feasible. This report presents data on the average wave climate for 10 selected offshore beach nourishment projects. These projects are listed and their locations shown in Figure 1.

2. The 10 projects covered by this report were chosen from 20 example projects described in Beach Nourishment Techniques Report 3.* The 20 projects were in turn derived from an updated version of the National Shoreline Study (NSS), a survey of U. S. coastal erosion conducted by the Office, Chief of Engineers.**

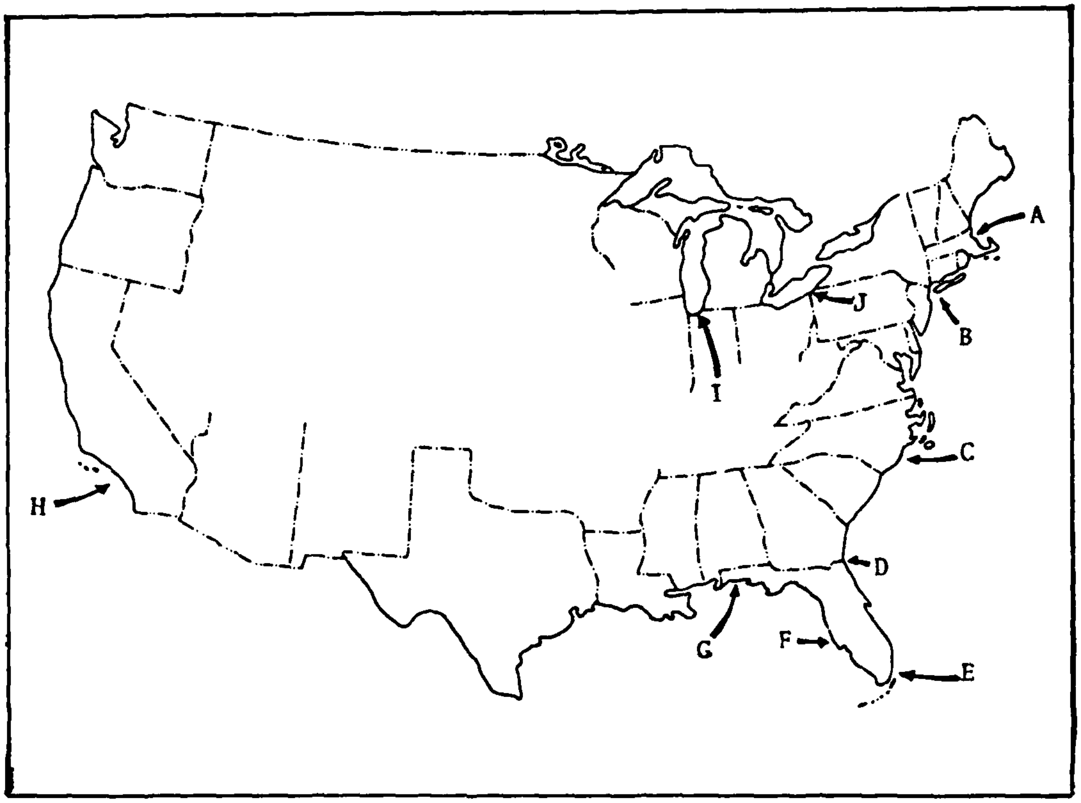
3. Wave information from this report will be used in Beach Nourishment Techniques Report 5 together with data from Report 3 to help evaluate the capability of various offshore dredging systems to perform beach nourishment work. This wave information will also provide input to preliminary engineering developments of those systems that appear promising. Various types of offshore dredging systems, both existing and proposed, were described in Beach Nourishment Techniques Report 1.†

---

* R. D. Hobson. 1981. "Beach Nourishment Techniques; Typical U. S. Beach Nourishment Projects Using Offshore Sand Deposits," Technical Report H-76-13, Report 3, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.

** Office, Chief of Engineers, Department of the Army. 1971. "Report on the National Shoreline Study," Washington, D. C.

† T. W. Richardson. 1976. "Beach Nourishment Techniques; Dredging Systems for Beach Nourishment from Offshore Sources," Technical Report H-76-13, Report 1, U. S. Army Engineer Waterways Experiment Station, CE, Vicksburg, Miss.



LEGEND

A REVERE BEACH, MASS
B ROCKAWAY BEACH, N Y
C CAROLINA BEACH, N C
D NASSAU COUNTY, FLA
E DADE COUNTY, FLA
F TREASURE ISLAND, FLA
G PANAMA CITY, FLA
H REDONDO BEACH, CALIF
I INDIANA DUNES, IND
J PRESQUE ISLE, PA

Figure 1. Beach nourishment project location map

PART II: DATA AND CALCULATIONS

Wave Exposure

4. The degree to which a potential beach nourishment site is open to the directional spectrum of wave energy from distant and local storms is called wave exposure. The amount of wave exposure along the coastline of the United States (including the Great Lakes) is dependent on the configuration of the mainland and the existence of offshore sheltering islands. Different locations along the coastline may be exposed to different wave climates (even at nearby locations) due to the physical orientation of the coastline and offshore islands causing wave exposure windows to vary. Hence, it is imperative that the particular area of interest be studied when determining the degree of wave exposure.

Data Sources

SSMO data

5. Using the best available deepwater wave data at the time of this analysis (1978), the average wave climate at each of 10 potential project locations was determined by considering the effects of offshore bathymetry on the characteristics of the incoming wave systems. For the sites on the Atlantic, Gulf, and Great Lakes, the deepwater wave characteristics were determined from the Synoptic Shipboard Meteorological Observation (SSMO) data tapes. The SSMO data tape family was derived from over 31 million surface marine observations obtained from ship's logs, ship weather reporting forms, published ship observations, automatic observing buoys, teletype reports, and data purchased from several foreign meteorological services. The quality of instruments used to make the measurements, as well as the qualifications of the observers, varied considerably. However, a diligent effort has been made to employ a common observational format, designed for use with modern electronic data processing equipment.

6. The surface of the earth has been divided into a grid of 648

elements, each 10 deg of latitude by 10 deg of longitude. Each of these elements (a Marsden Square) has been further divided into 100 subsquares. Each Marsden Square and each subsquare has been uniquely numbered, and all surface marine observations have been stored in the appropriate Marsden Square and subsquare. To determine from the SSMO data tapes the deepwater wave climate for any of the selected beach nourishment sites, the site location coordinates are used to isolate the appropriate Marsden Square and the corresponding subsquare. When the area of interest is sufficiently large to completely encompass a subsquare, or lies at the intersection of several subsquares, a combined table of statistics is requested. This allows the information from each subsquare to be developed into one composite table of statistics. Each site being considered in this investigation required evaluation of 2 to 6 subsquares of data (Table 1).

Redondo Beach data

7. The deepwater wave climate for the Redondo Beach, Calif., site was determined from hindcast wave statistics developed for the California Department of Navigation and Ocean Development (DNOD). The U. S. Navy Fleet Numerical Weather Central (FNWC) has produced synoptic wave analyses for the northern hemisphere since 1946. These data are stored on magnetic tape and recently have been utilized by Meteorology International, Inc. (MII) under contract with DNOD to provide deepwater wave statistics for coastal engineering applications. These statistics are similar to those previously prepared by National Marine Consultants and by Marine Advisers (MA), which have been the basis of design for many coastal projects in California. The statistics by MII not only increase the wave data base from 3 years to 29 years, but also reduce the wave direction increments from 22-1/2 deg to 10 deg and provide additional information on persistence of waves of various heights. These deepwater, open-wave statistics compiled from a 29-year data base (1946-1974) are available from DNOD for six stations along the California coast.

8. The singular wave model used by FNWC is based upon converting barometric observations from ship and shore stations into a pressure field. A wind field is mathematically derived from this pressure field

and imposed on a grid covering the northern hemisphere. At each grid point wave heights, periods, and directions are mathematically generated for each 24-hr period. If the generated wind wave is 5 ft (1.52 m) or more in height, a swell train is initiated along a great circle track in the same direction as the wind wave and carried from grid point to grid point until the swell decays to less than 3 ft (0.91 m) or reaches land. At each grid point, both the wind wave (sea) and a swell wave are thus determined and recorded. However, the FNWC grid system does not follow the California coastline, and it was deemed desirable by DNOD to have deepwater statistics available near the coast. Six locations for such statistics were chosen by MII and DNOD. Station 5 is located directly off Redondo Beach, Calif., in deepwater so that island effects not considered by the numerical model are avoided.

9. Because the DNOD data do not include any southern hemisphere swell considerations, the most comprehensive source of southern hemisphere swell information continues to be the MA data, which were used to supplement DNOD data. Also, Santa Monica Bay, in which Redondo Beach is located, is sufficiently large so that local sea waves with periods up to 5 sec may occasionally be generated. Accordingly, wind data from the SSMO data tapes were used to hindcast a local wind wave field in Santa Monica Bay.

10. In recent months, questions have arisen regarding the applicability of a singular wave model for the determination of wave statistics. Most knowledgeable researchers agree that the spectral approach is significantly better and, indeed, the U. S. Army Engineer Waterways Experiment Station is presently engaged in a 5-year project to provide, through hindcasting, directional spectral wave climatology for all continental United States coastlines and Hawaii. This wave climatology ultimately will be available in the form of a computer-based wave information system with the capability to perform nearshore wave transformations such as those necessary for the present study. However, the data results applicable to this study were not scheduled to be available until the latter part of 1982, and it was not possible to delay initiation of an investigation of the wave climate at selected beach nourishment locations until

that time. Consequently in 1978 when this study was undertaken, the only viable alternative was to proceed with analyses based upon the best available wave information, which was believed to be MII statistics for northern hemisphere swell and decayed sea waves for the coast of California, MA statistics for southern hemisphere swell for the coast of California, and the SSMO data tapes from which locally generated sea and swell waves can be determined for all other potential nourishment sites. Results and conclusions for each site can be revised, if necessary, as more reliable wave data become available.

Redondo Beach Island Sheltering Effects

11. The wave data for Redondo Beach had to be adjusted to include the sheltering effects of offshore islands. If the coastline were not sheltered by offshore islands, waves would arrive from a wide range of directions even if the direction of the wind in the generating area were relatively constant. Wave direction can vary within a path of at least 45 deg on each side of the wind. A wave intensity directional beam pattern of the form $(1 + \cos 2\theta)$ has been used in this study to approximate this directional variation. Intensity is assumed proportional to the square of the wave height, which is consistent with observed data. The result of sheltering, then, is to block a segment of this beam pattern and therefore prevent certain parts of the wave-height directional distribution from reaching the protected area.

12. In investigating island sheltering, the first consideration is to determine which directions of approach are open to waves of various periods and which are blocked. This cannot be accomplished by simply inspecting the sea level contours of the islands, for shallow water can act as a barrier just as effectively as an island shore. The blocking action depends on both water depth and wave period, with long-period waves requiring deeper water for passage than shorter period waves. As a result, any given opening between two islands will present a narrower portal to a long-period wave than it will to a short-period wave. With the aid of precise bottom-contour charts, all such avenues of approach

were determined for the Redondo Beach, Calif., site, and the required integrations were performed by digital computer. The results of these computations are presented in later portions of this report.

13. The island sheltering theory yields not only height-reduction ratios but indicates modification in direction as well. Periods are assumed to remain unchanged. The direction modifications are necessary because, in some cases, sheltering will block out part or all of the central portion of the wave direction beam. When this happens, the wave energy reaching the hindcast point will obviously come from around the two ends of the barrier, and the resulting modified wave train will come from a direction within the original sector but modified toward that end of the barrier around which the larger part of the remaining wave energy came. The island sheltering coefficients, or the percent remaining of the original deepwater wave heights, and the direction-of-approach alterations were applied to the deepwater wave climate being utilized in this analysis. The resulting sheltered deepwater wave climate was then refracted shoreward to the site of interest.

Refraction and Shoaling Effects

14. The phase velocity (celerity) of a surface gravity wave depends on the depth of water through which the wave propagates. As the wave celerity decreases in shallower water, the wavelength must also decrease for the period to remain constant. Variation in celerity occurs along the crest of a wave moving at an angle to underwater contours, because that part of the wave in deeper water is moving faster than the part in shallow water. This variation causes the wave crest to bend toward alignment with the contours. This bending effect, called refraction, depends on the relation of water depth to wavelength. It is analogous to refraction of other types of waves, such as light or sound.

15. As waves propagate from deep water into shallow water, changes other than refraction take place. For instance, the wave height will change solely due to the changing water depth. This effect is called shoaling, and it varies in both magnitude and direction (the shoaled

height can be either more or less than the deepwater height, depending on the water depth relative to a given wave). Also, the assumptions are often made that there is no loss of wave energy and negligible reflection for waves propagating into shallower water. Therefore, the power being transmitted by the wave train in water of any depth is equal to the power being transmitted in deep water. The wave period remains constant in water of any depth, whereas the length, velocity, and height vary.

16. The transformation of irregular ocean waves is a complex process which is not fully understood. The usual method of treating the problem (which is both practical and relatively successful) is to represent the actual system by a series of sinusoidal waves of different heights, periods, and phases. Such a system has a two-dimensional energy spectrum. The wave statistics analyzed in the present study were treated in this manner.

17. Refraction and shoaling effects are important for several reasons. These phenomena determine the wave height in any particular water depth for a given set of incident deepwater conditions, those conditions being wave height, period, and direction of propagation in deep water. Refraction and shoaling, therefore, have a significant influence on the distribution of wave energy along the coast. The change in direction of different parts of the wave results in convergence or divergence of wave energy and materially affects the force which can be exerted on, say, a floating dredge and alters the capacity of waves to transport sediment.

18. A refraction analysis was performed at each project location to determine the effects of bathymetry on the incoming deepwater wave climate. At each site an area sufficiently large to delineate the waves arriving from all possible directions was overlain by a bathymetric grid with 366-m spacing (except Redondo Beach, Calif., where the local topography steepness required that a 122-m grid be used). The number of grid lines in the x- and y-directions varied, depending upon the local geometry, as given in Table 2. Also given in Table 2 are the ranges of deepwater wave approach directions used for each site. In performing a

refraction analysis, the ranges were divided into 30-deg segments and the center direction of each segment was used to represent the entire segment. For example, the 30-deg segment from 75 to 105 deg would be represented by wave rays with a deepwater azimuth of 90 deg. The next segment, 105 to 135 deg would be represented by the 120-deg direction, and so forth. The result of this approach was that the deepwater wave directions actually used as input to the refraction analysis were all whole multiples of 30 deg (30, 60, 90, etc.). The range of deepwater approach for each site was selected to cover the entire range of possible approach angles to the bathymetric grid used for refraction analysis. In some cases, such as Revere Beach, this range of approach directions was restricted by coastal landforms not covered by a project site map.

19. The wave-height coefficients* and the altered directions-of-approach were determined at each of the potential sites. These coefficients and new propagation directions were applied to the deepwater wave statistics, and the frequencies of occurrence were redistributed according to the combined refraction and shoaling effects. The assumption was made in the redistribution process that the original distribution in a wave-height band of the deepwater wave statistics was uniform over the band width. This permitted the new tables to appear in the same form (same equal spacing of wave-height bands) as the original tables of frequencies. For example, if 20 percent of the waves were between 5 and 6 m high in deep water, and if the wave-height coefficient was 0.70 at the dredge site, 20 percent of the refracted waves would exist between 3.5 and 4.2 m at the dredge site. However, by assuming a uniform distribution, the conclusion is made that 14 percent of the waves exist between 3 and 4 m and 6 percent exist between 4 and 5 m at the dredge site.

20. The wave-height coefficients (combined refraction and shoaling coefficients) and the directions-of-approach at the project locations,

---

* The wave-height coefficient is the ratio of the wave height at a selected point to the deepwater wave height. It is the product of the refraction and shoaling coefficients.

which were determined for each of the potential sites, are presented in Appendix A. These data were determined by applying the appropriate grid from Table 2, which was sufficiently large to completely encompass the region of significance. The deepwater wave climate (DNOD for Redondo Beach, Calif., SSMO for all other sites) was input at the grid boundary and refracted to the project location. Here the direction-of-approach of each wave-period input at the grid boundary was obtained, and the wave-height coefficients were applied to the corresponding deepwater input statistics. The refraction process resulted in many deepwater directions-of-approach arriving at the project location from the same general approach azimuths. This grouping or combining of several wave directions at the site (each requiring a redistribution of the wave statistics in the frequency bands) was efficiently manipulated by digital computer. The Redondo Beach site required a double-pass process since the effect of the sheltering islands on the deepwater wave climate is essentially equivalent to a previous refraction process (an alteration in direction-of-approach and a reduction in wave heights appropriate to the input characteristics). The island sheltering coefficients for Redondo Beach are also displayed in Appendix A. In Part III, a brief description is given of assumptions and guidelines used at each site, which will assist in understanding the format of information in Appendix A.

PART III: PROJECT SITES

21. Figures 2 through 11 show the locations of the fill and borrow sites, surrounding area, and general offshore bathymetry at each of the 10 selected beach nourishment project sites. For some of these sites, certain simplifications were made to expedite calculation of the average wave climate. These simplifications are described briefly in the following paragraphs. More detailed descriptions of these and 10 other example beach nourishment project sites can be found in Beach Nourishment Techniques Report 3 (Hobson, 1981).

Revere Beach, Mass.

22. As shown in Figure 2, the borrow area for Revere Beach lies approximately 12.5 km offshore in 27 m of water. Revere Beach itself is in a partly sheltered location with rather complex offshore bathymetry and surrounding landforms. Due to the convoluted refraction effects of this bathymetry, it was not feasible to refract deepwater waves into the Revere Beach area. Consequently, the average yearly wave climate was determined for the borrow area only.

Rockaway Beach, N. Y.

23. Figure 3 shows the Rockaway Beach project as well as the borrow area used in Beach Nourishment Report 3 for beach fill calculations. In a reverse case of that described for Revere Beach, however, the borrow area for Rockaway is positioned such that refraction diagrams are difficult to construct. Therefore, the average wave climate was calculated for an area between the fill project and an alternate borrow area lying roughly 2 km offshore parallel to the fill project.

Carolina Beach, N. C.

24. The Carolina Beach nourishment project encompasses two borrow

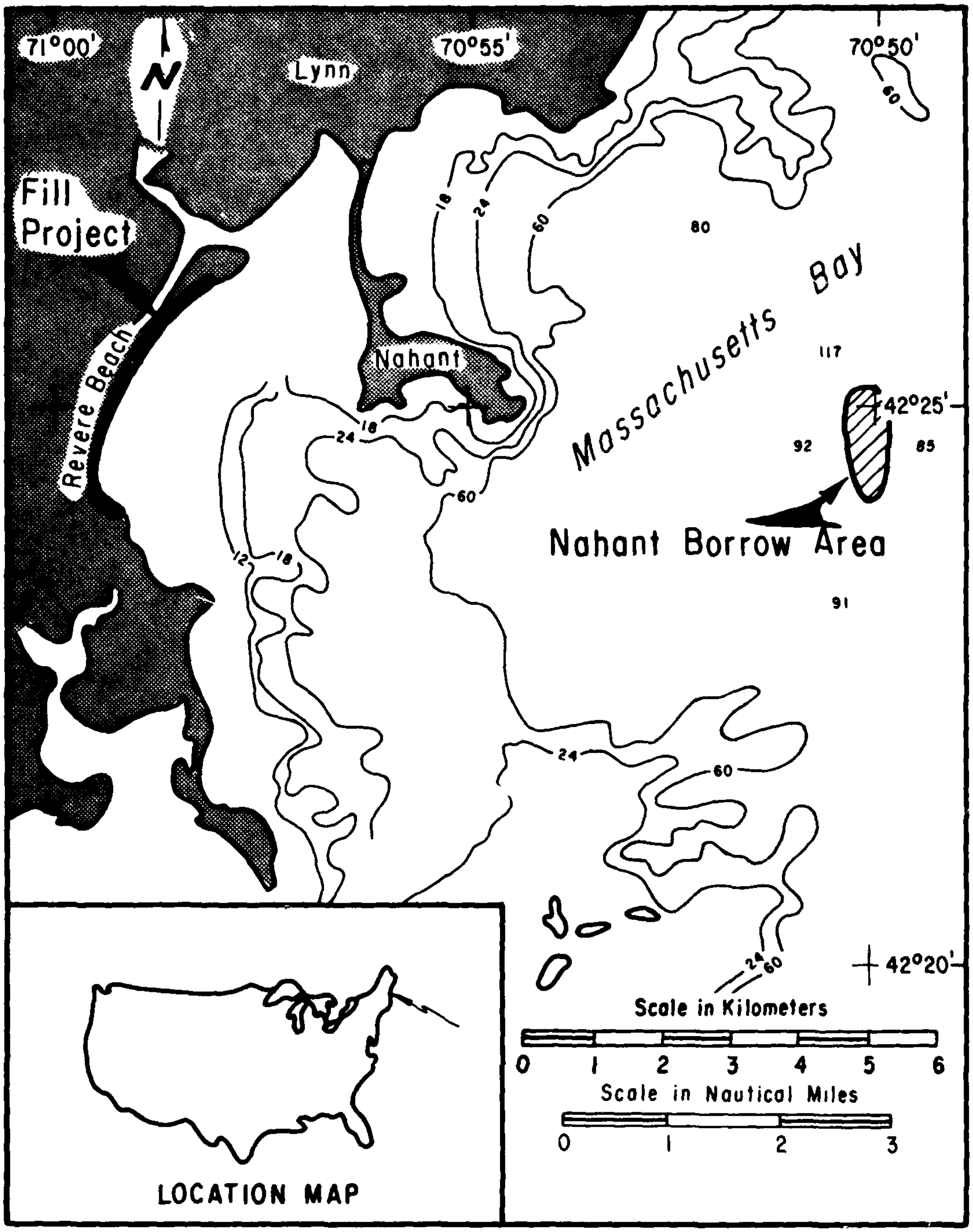


Figure 2. Location and bathymetry; Revere Beach, Mass. (depth contours in feet) (feet × 0.3048 = metres)

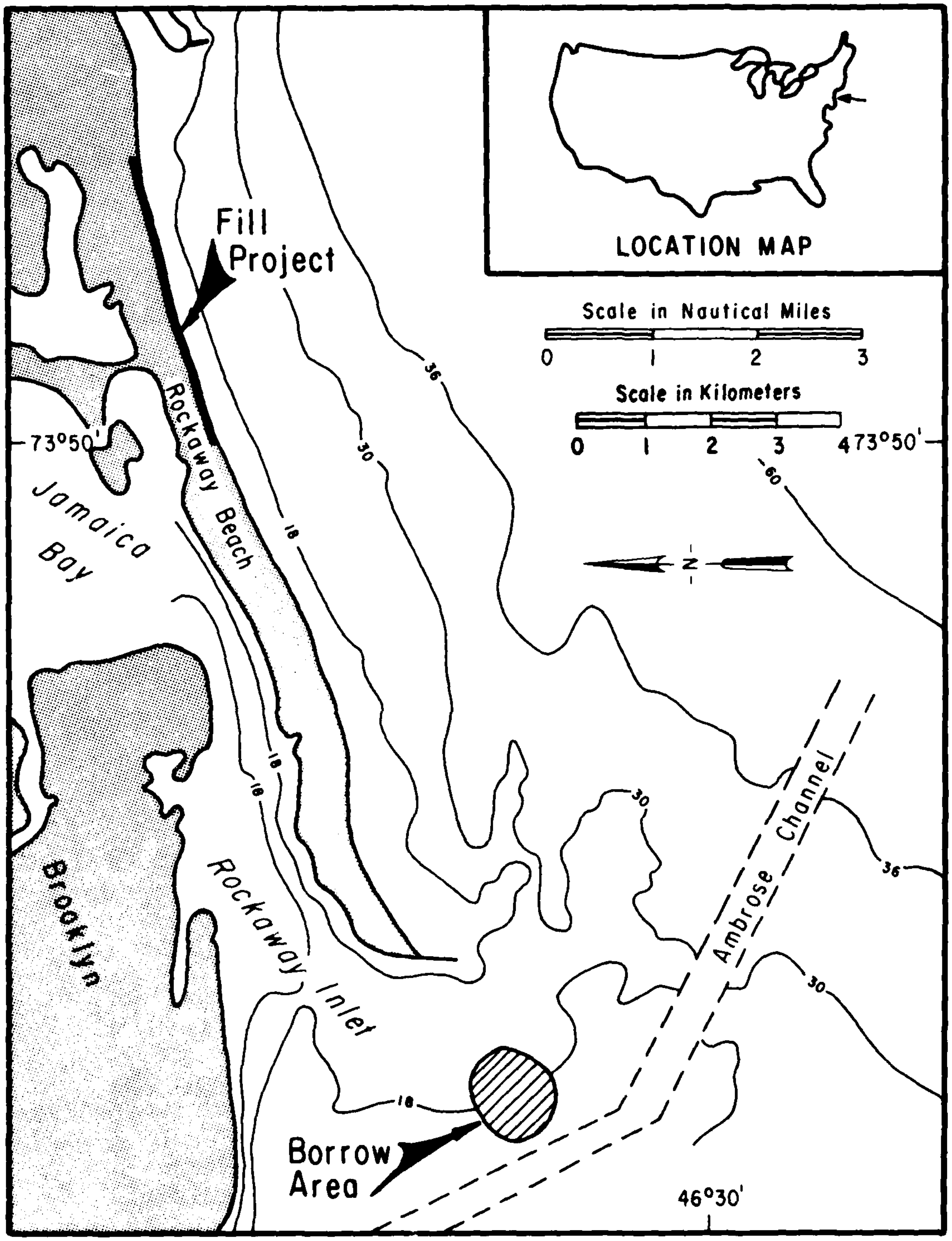


Figure 3. Location and bathymetry; Rockaway Beach, N. Y. (depth contours in feet)

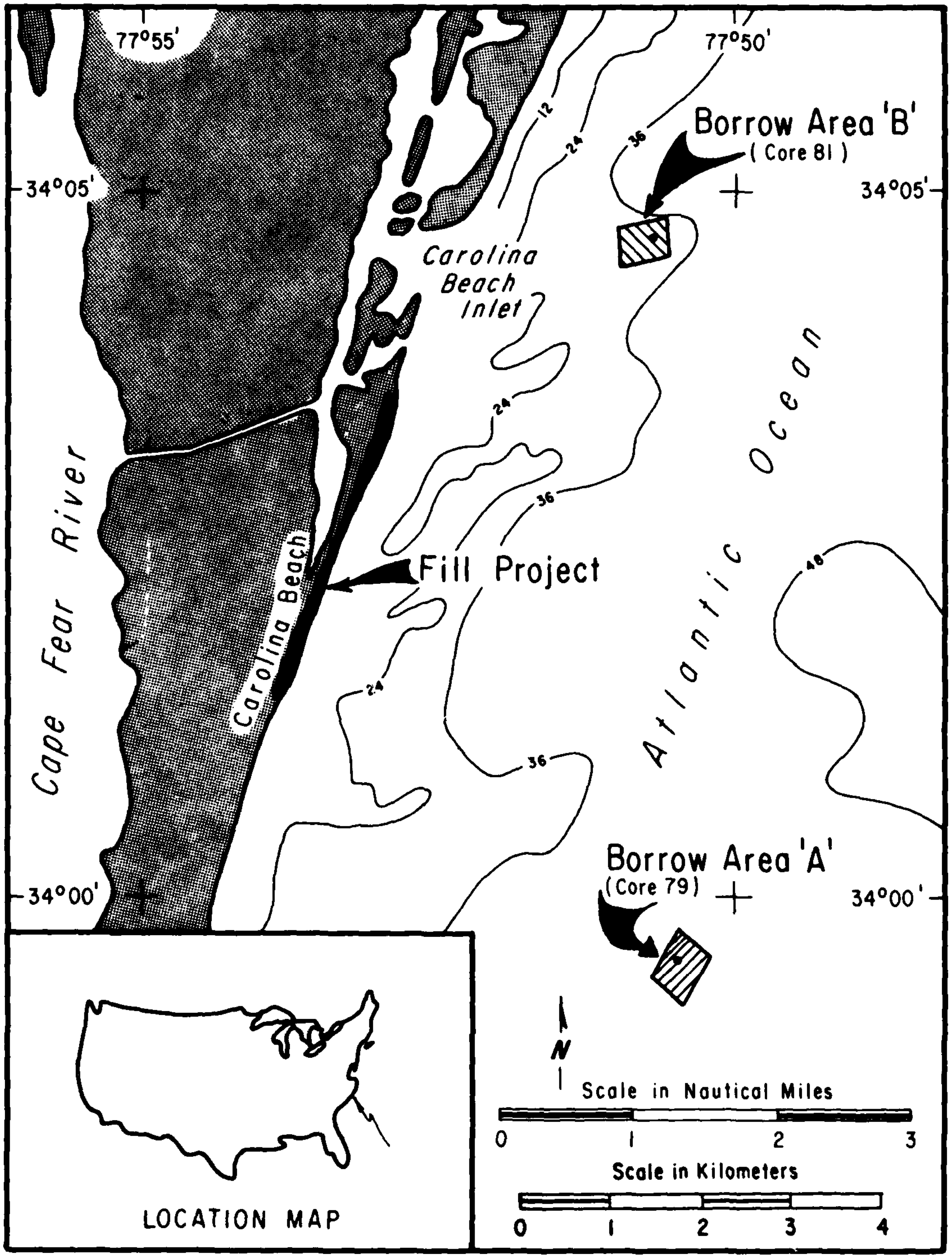


Figure 4. Location and bathymetry; Carolina Beach, N. C.
(depth contours in feet)

areas, as shown in Figure 4. An average wave climate was calculated along a segment of a line connecting these two borrow areas, thus providing information representative of both areas. In addition, an average wave climate was calculated for the fill project area, since the borrow areas are in approximately 13 m of water and the wave conditions will be substantially affected by decreasing depth between the borrow and fill sites.

Nassau County and Dade County, Fla.

25. At both of these project sites (Figure 5 and 6, respectively), the offshore borrow areas are close to the fill project. Therefore, at both sites, one average wave climate was calculated for an area between the borrow and fill areas.

Treasure Island, Fla.

26. At Treasure Island, the borrow area is immediately offshore of the fill project, in approximately 4 m of water (Figure 7). Since there are no radical changes in bathymetry between the borrow and fill areas, the wave climate at both locations will be approximately the same. Accordingly, an average wave climate was calculated for the fill project area and assumed to be representative of the borrow area as well.

Panama City, Fla.

27. Figure 8 shows the Panama City project site and borrow area. The borrow area is located offshore of the fill project in approximately 9-m water depth. An average wave climate for the project was calculated for an area between the fill and project sites.

Redondo Beach, Calif.

28. The bathymetry offshore of Redondo Beach drops rather steeply

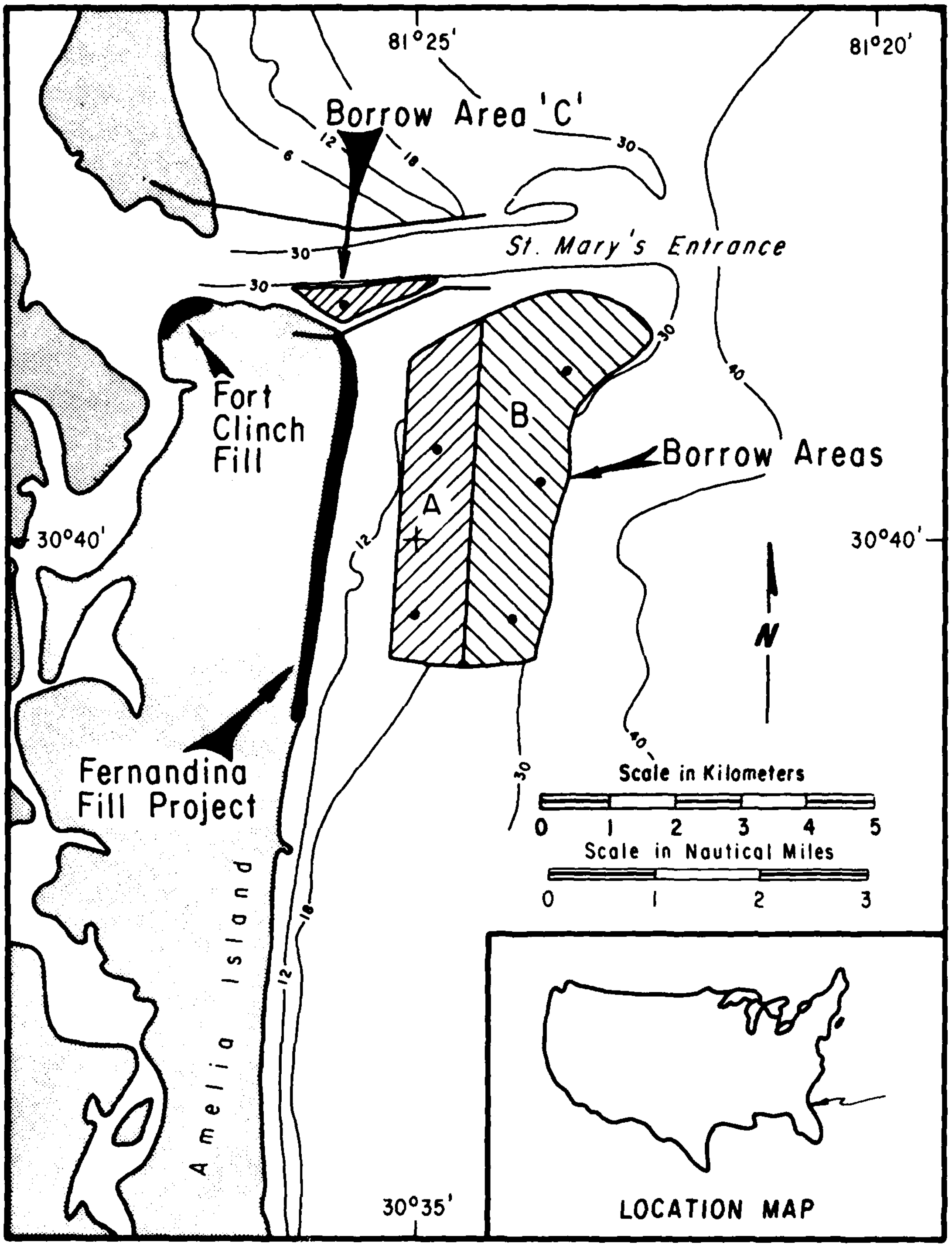


Figure 5. Location and bathymetry; Nassau County, Fla.
(depth contours in feet)

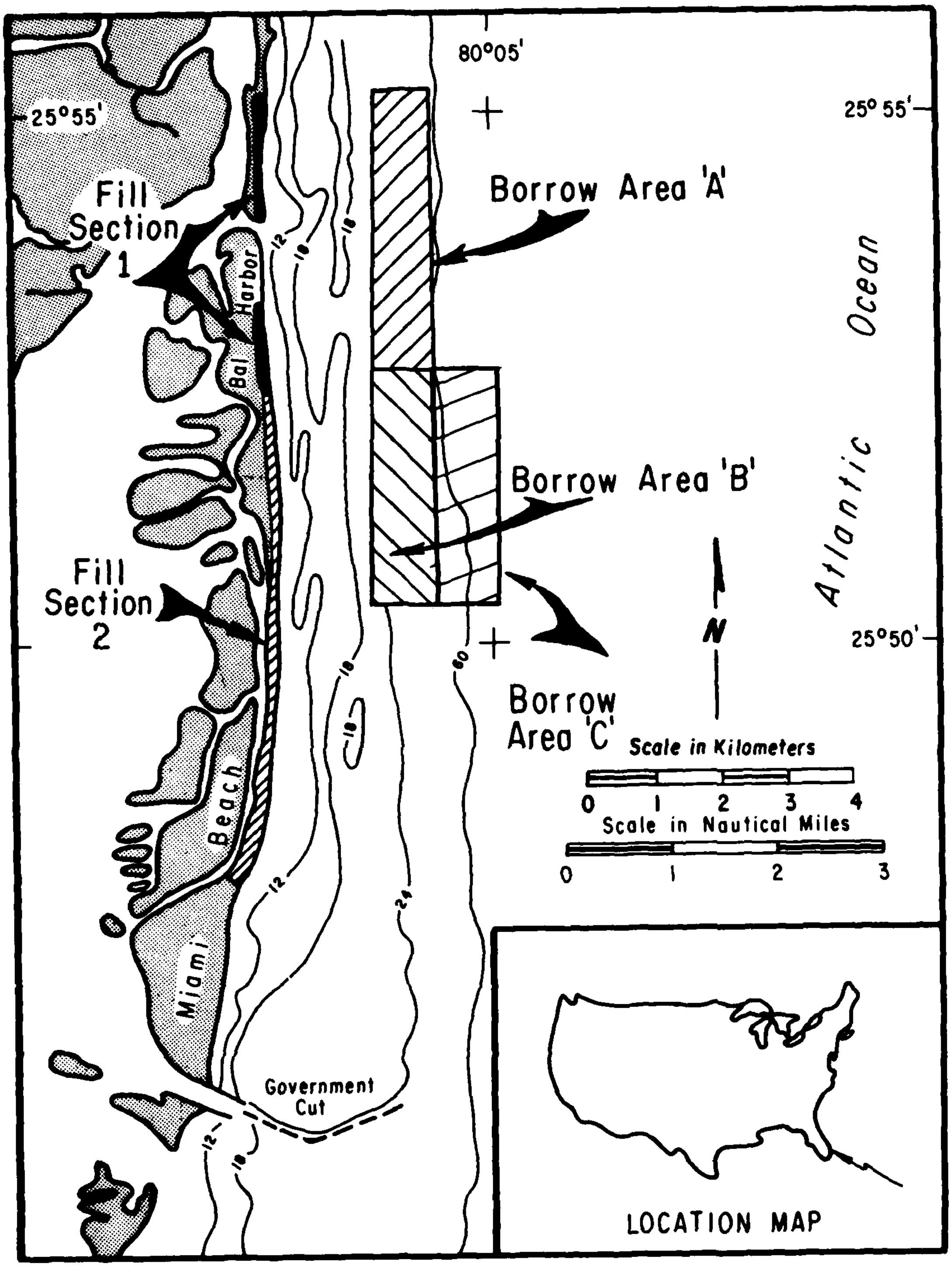


Figure 6. Location and bathymetry; Dade County, Fla.
(depth contours in feet)

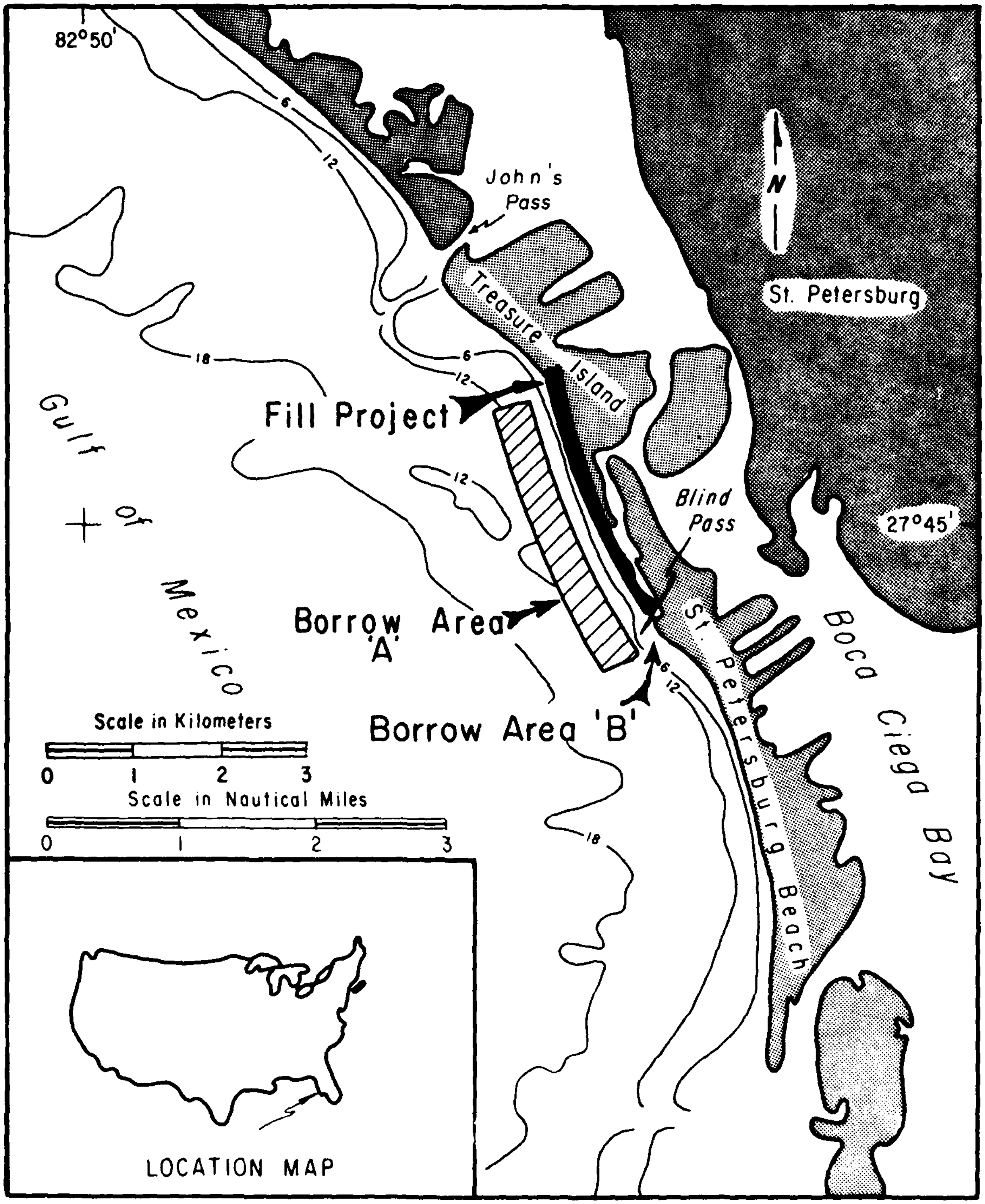


Figure 7. Location and bathymetry; Treasure Island, Fla.
(depth contours in feet)

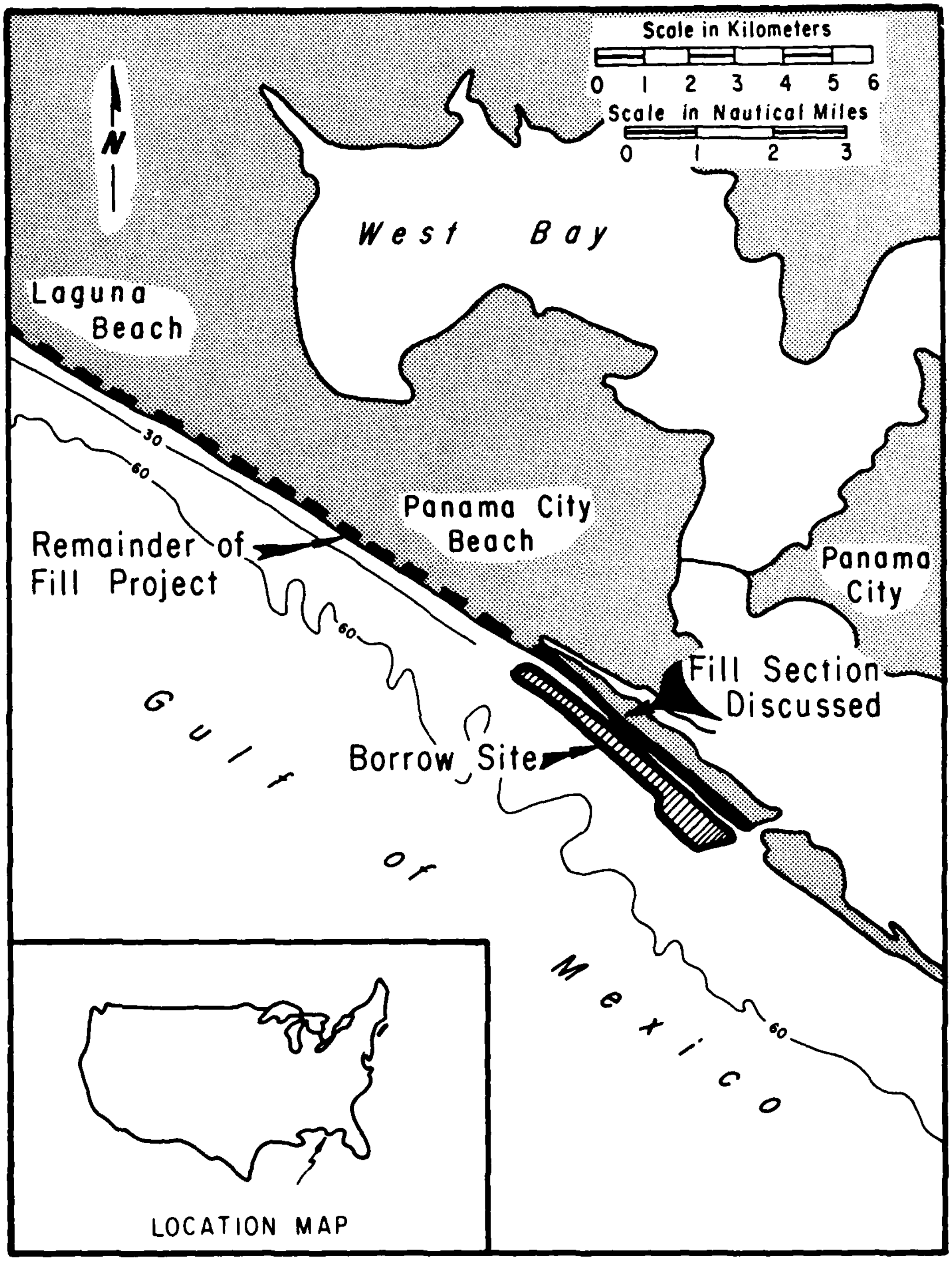


Figure 8. Location and bathymetry; Panama City, Fla. (depth contours in feet)

and quickly into a submarine canyon which extends almost to shore (Figure 9). The borrow area is located in water depths varying from 9 to 18 m and lies approximately 2 km offshore of the fill project. The bathymetry seaward of the borrow area continues downward into the submarine canyon. It was decided that, for the purposes of this study, the effects of bathymetry seaward of the borrow area on incoming wave heights can be ignored. Therefore, the sheltered deepwater wave-height climate can be used as the wave-height climate for the borrow area. A separate wave-height climate was calculated for the fill area.

Indiana Dunes, Ind.

29. The borrow areas for Indiana Dunes, although several kilometers away along the shore from the fill project (Figure 10), are located adjacent to shore with much the same offshore bathymetry as the fill project. Therefore, the wave-height climate will be approximately the same, and the climate was calculated for the fill project area only.

Presque Isle, Pa.

30. The borrow area for Presque Isle (Figure 11) is located 12 km lakeward of the fill project in 17 m of water. As with Redondo Beach, it was decided to use the deepwater wave-height climate for statistics in the borrow area. A separate wave-height climate was calculated for the fill project area.

and quickly into a submarine canyon which extends almost to shore (Figure 9). The borrow area is located in water depths varying from 9 to 18 m and lies approximately 2 km offshore of the fill project. The bathymetry seaward of the borrow area continues downward into the submarine canyon. It was decided that, for the purposes of this study, the effects of bathymetry seaward of the borrow area on incoming wave heights can be ignored. Therefore, the sheltered deepwater wave-height climate can be used as the wave-height climate for the borrow area. A separate wave-height climate was calculated for the fill area.

Indiana Dunes, Ind.

29. The borrow areas for Indiana Dunes, although several kilometers away along the shore from the fill project (Figure 10), are located adjacent to shore with much the same offshore bathymetry as the fill project. Therefore, the wave-height climate will be approximately the same, and the climate was calculated for the fill project area only.

Presque Isle, Pa.

30. The borrow area for Presque Isle (Figure 11) is located 12 km lakeward of the fill project in 17 m of water. As with Redondo Beach, it was decided to use the deepwater wave-height climate for statistics in the borrow area. A separate wave-height climate was calculated for the fill project area.

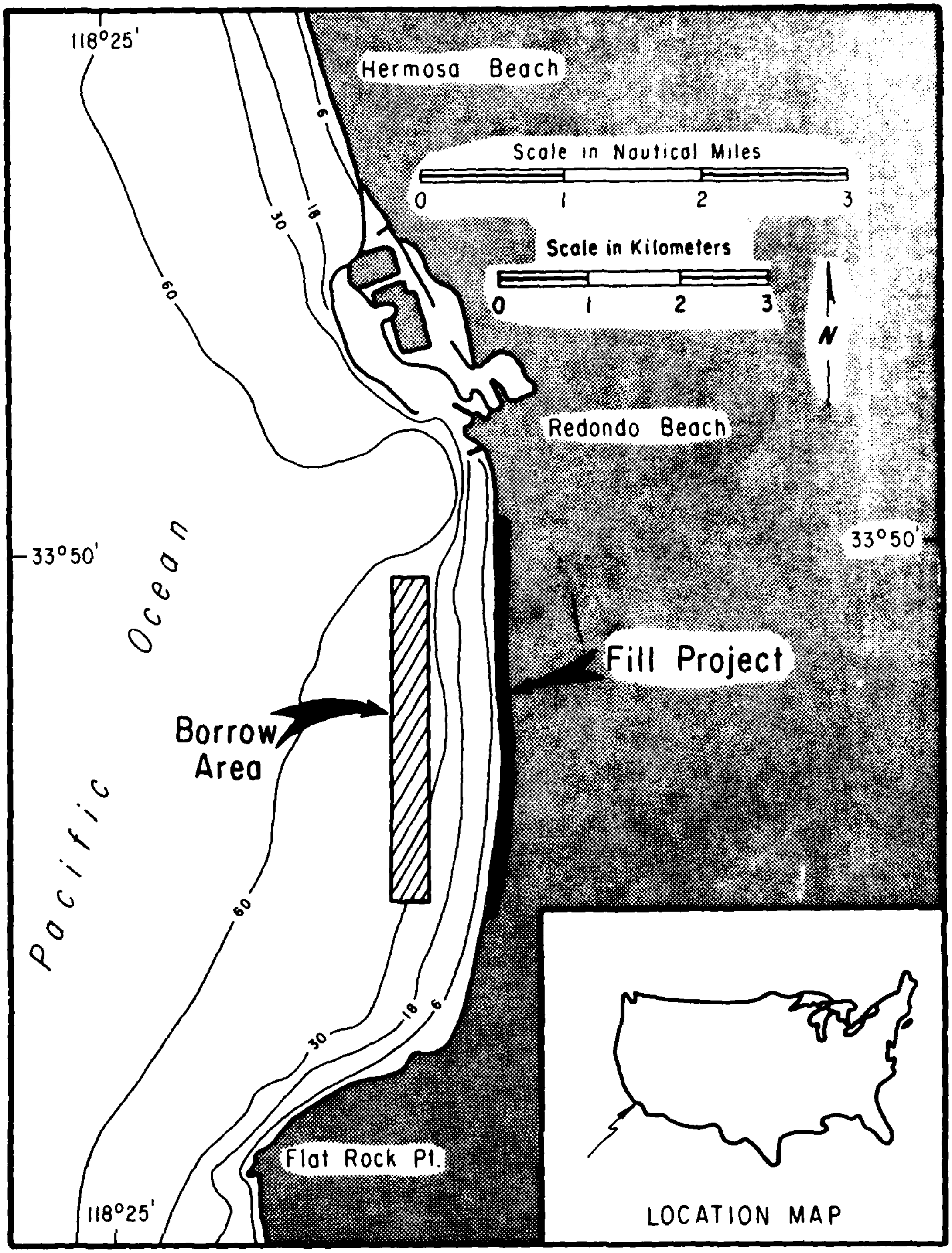


Figure 9. Location and bathymetry; Redondo Beach, Calif. (depth contours in feet)

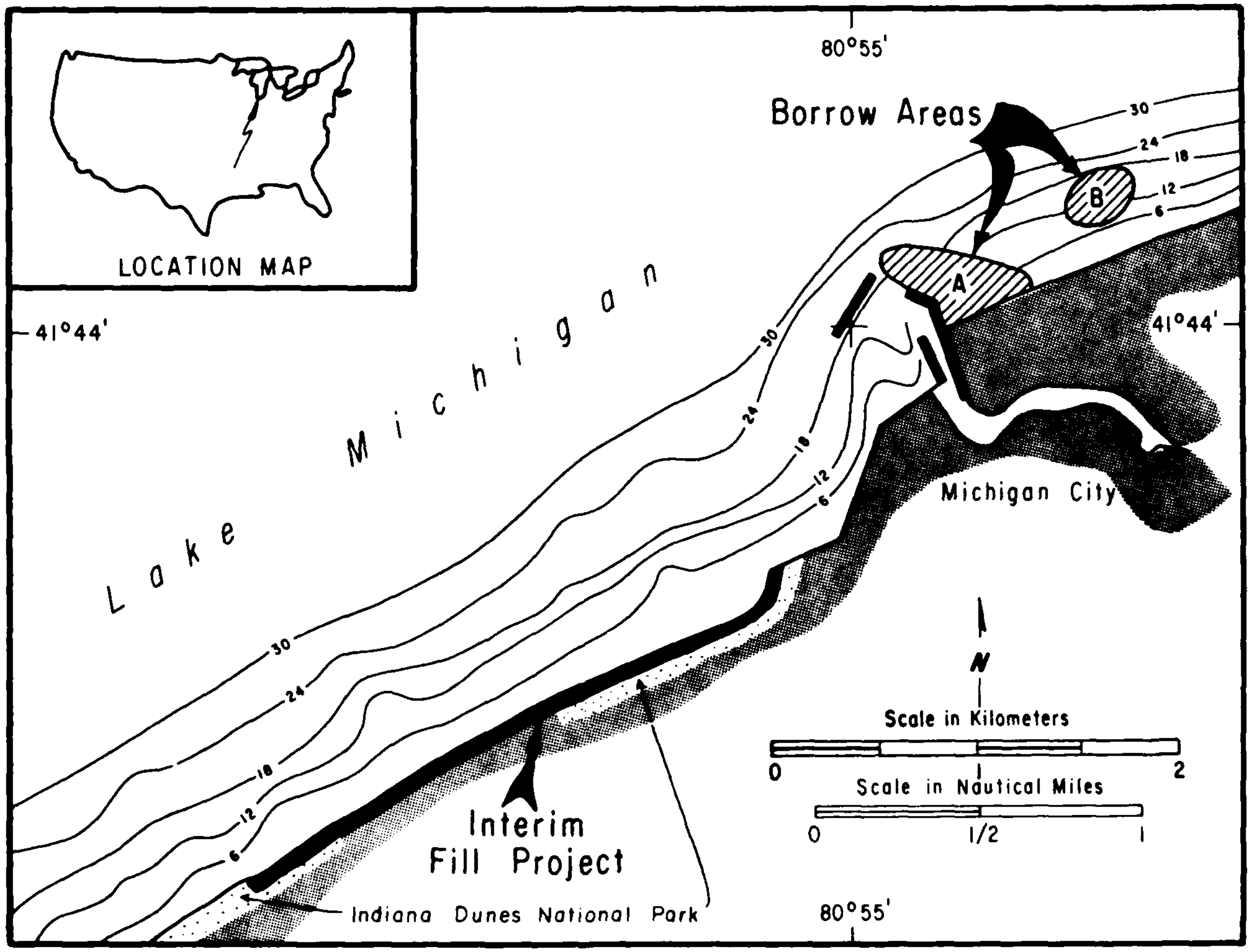


Figure 10. Location and bathymetry; Indiana Dunes, Ind. (depth contour in feet)

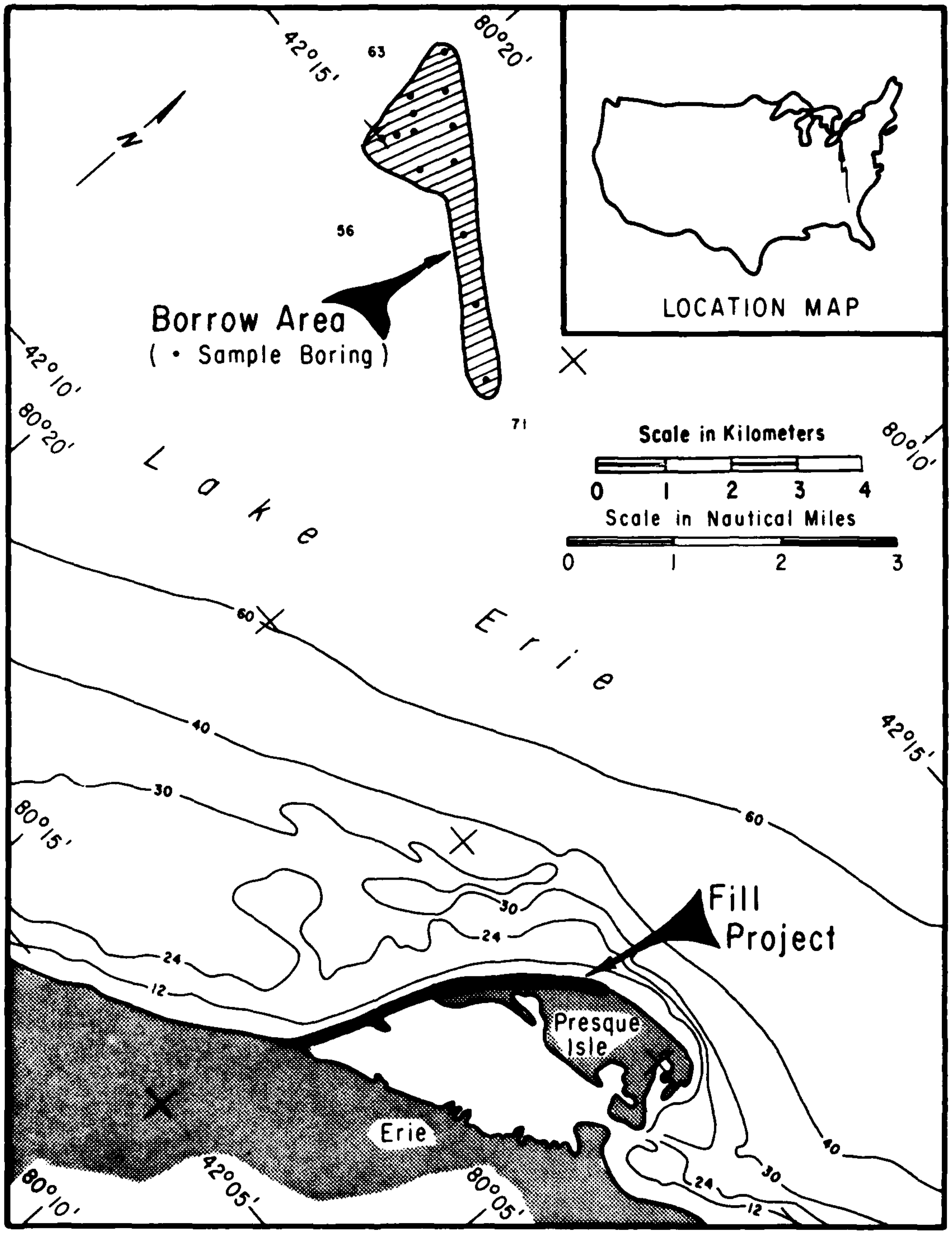


Figure 11. Location and bathymetry; Presque Isle, Pa. (depth contours in feet)

PART IV: WAVE DATA

31. The results of wave climate calculations for each of the 10 selected projects are presented in several forms, both graphical and tabular. In summary form, Tables 3 through 15 give the annual percent occurrences of wave-height/period combinations by classes. Plates 1-13 show the occurrence of significant wave heights in terms of the total percent time per year that these heights are exceeded (on a long-term average basis).

32. Appendixes B through K give more detailed information on the average wave climate at each site. Each appendix contains the following:

- a. Tabulations of monthly percent occurrence of wave-height/period combinations.
- b. Tabulations of annual percent occurrence by azimuth direction of wave-height/period combinations.
- c. Plots of monthly significant wave-height occurrence in terms of the total percent time per month that these heights are exceeded.

33. Table 16 summarizes the tables, figures, and appendixes which apply to each project site.

PART V: SUMMARY

34. Data are presented describing the average wave climate at 10 selected sites which are potential beach nourishment projects where offshore sand sources exist. Deepwater wave data for 9 of the 10 sites were obtained from SSMO data tapes. Data for the tenth site, which is located on the California Pacific coast, came from DNOD files.

35. Analyses performed on the deepwater data include the calculation of island sheltering, refraction, and shoaling effects. Tables and plots of wave height/period frequency distributions on a monthly, annual, and azimuth of approach basis are presented as a means of summarizing the results of these calculations.

36. The data in this report are intended to provide information on wave exposure at the selected sites and at the sand borrow areas. Subsequent work will use this information to evaluate the capability of various offshore dredging systems to perform the beach nourishment work.

Table 1

Synoptic Shipboard Meteorological Observation

Data Sets of Sites Studied

Site	Marsden Squares	Subsquares
Revere Beach, Mass.	151	28, 29, 38, 39
	152	20, 30
Rockaway Beach, N. Y.	152	02, 03
	116	92, 93
Carolina Beach, N. C.	116	36, 37, 46
Nassau Co., Fla.	117	00, 10
	081	90
Dade Co., Fla.	080	59, 69
Treasure Island, Fla.	081	63, 64, 73, 74, 83, 84
Panama City, Fla.	117	05, 06
	081	95, 96
Redondo Beach, Calif.	(Did not use SSMO data)	
Indiana Dunes, Ind.	153	16, 17, 26, 27
Presque Isla, Pa.	153	20
	152	29

Table 2

Grid Sizes and Wave Approach Directions

Site	Grid Size (No. Lines × No. Lines × Spacing, m)	Deepwater Wave Approach Directions, deg (Azimuth from True North)
Revere Beach, Mass.	97 × 125 × 366	15-105
Rockaway Beach, N. Y.	97 × 126 × 366	75-195
Carolina Beach, N. C.	75 × 65 × 366	15-195
Nassau Co., Fla.	101 × 113 × 366	345-195
Dade Co., Fla.	53 × 21 × 366	345-195
Treasure Island, Fla.	53 × 62 × 366	165-345
Panama City, Fla.	89 × 69 × 366	135-315
Redondo Beach, Calif.	130 × 90 × 122	155-335
Indiana Dunes, Ind.	87 × 82 × 366	285-75
Presque Isle, Pa.	43 × 37 × 366	255-75

Table 3

REVERE BEACH DREDGE SITE

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC)										TOTAL
	<5-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	>22	
00-01	39.31	1.74	0.97	0.09	0.05	0.05	0.00	0.00	0.02	0.14	42.37
01-02	33.98	5.18	1.50	0.19	0.29	0.07	0.00	0.00	0.00	0.03	41.24
02-03	5.99	3.14	1.35	0.22	0.19	0.20	0.00	0.00	0.00	0.00	11.10
03-04	0.96	1.14	0.85	0.19	0.18	0.16	0.00	0.00	0.00	0.00	3.49
04-05	0.23	0.33	0.42	0.13	0.05	0.05	0.00	0.00	0.00	0.00	1.20
05-06	0.17	0.04	0.20	0.13	0.04	0.05	0.00	0.00	0.00	0.00	0.63
06-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	80.64	11.58	5.28	0.94	0.81	0.58	0.00	0.00	0.02	0.18	

Table 4

ROCKAWAY BETWEEN FILL AND DREDGE SITES

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC)										TOTAL
	<5-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	>22	
00-01	36.45	3.22	1.71	0.62	0.44	0.21	0.05	0.03	0.30	0.44	43.47
01-02	29.20	7.81	3.19	0.85	0.37	0.15	0.03	0.01	0.08	0.06	41.74
02-03	3.10	5.07	1.43	0.58	0.21	0.07	0.01	0.00	0.01	0.04	10.51
03-04	0.40	1.86	0.42	0.15	0.08	0.03	0.01	0.01	0.01	0.00	2.96
04-05	0.06	0.69	0.06	0.07	0.05	0.03	0.02	0.00	0.01	0.00	0.98
05-06	0.01	0.20	0.01	0.01	0.05	0.03	0.02	0.00	0.01	0.00	0.35
06-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	69.22	18.84	6.82	2.28	1.10	0.51	0.18	0.05	0.42	0.54	

NOTE: Number of observations = 9202

Table 5

CAROLINA BEACH DREDGE SITE

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC)										TOTAL
	<5-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	>21	
00-01	19.82	1.59	0.55	0.15	0.09	0.02	0.02	0.01	0.17	0.38	22.81
01-02	31.51	11.13	2.87	0.78	0.28	0.11	0.02	0.02	0.09	0.15	46.97
02-03	6.88	7.06	4.06	1.43	0.44	0.17	0.01	0.01	0.04	0.03	20.13
03-04	1.54	2.01	1.72	1.08	0.33	0.13	0.03	0.01	0.02	0.01	6.88
04-05	0.34	0.45	0.51	0.37	0.19	0.08	0.03	0.01	0.01	0.01	2.00
05-06	0.10	0.09	0.14	0.09	0.08	0.04	0.01	0.00	0.00	0.00	0.56
06-07	0.09	0.04	0.05	0.05	0.05	0.05	0.01	0.00	0.00	0.01	0.35
07-08	0.03	0.04	0.03	0.02	0.01	0.05	0.01	0.00	0.00	0.00	0.19
08-09	0.00	0.01	0.01	0.01	0.01	0.02	0.01	0.00	0.00	0.00	0.08
09-10	0.00	0.00	0.01	0.01	0.01	0.00	0.00	0.01	0.00	0.00	0.04
TOTAL	60.38	22.43	9.96	4.00	1.40	0.67	0.16	0.08	0.34	0.59	

Table 6

CAROLINA BEACH FILL SITE

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC)										TOTAL
	<5-5	6-7	8-9	10-11	12-13	14-15	16-17	18-19	20-21	>21	
00-01	22.14	3.65	0.80	0.19	0.10	0.02	0.01	0.01	0.16	0.33	27.41
01-02	30.17	9.34	2.74	0.67	0.19	0.06	0.01	0.01	0.09	0.17	43.45
02-03	8.01	9.45	6.42	3.13	1.20	0.59	0.13	0.05	0.09	0.09	29.17
03-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	60.33	[illegible]	[illegible]	4.00	[illegible]	0.67	[illegible]	[illegible]	0.34	0.59	

Table 7

NASSAU BETWEEN FILL AND DREDGE SITES

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC)										TOTAL
	<5-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	>22	
00-01	38.91	9.07	4.03	1.03	0.27	0.12	0.09	0.01	0.15	0.76	54.43
01-02	21.60	8.17	2.96	1.31	0.38	0.26	0.02	0.01	0.02	0.14	34.86
02-03	6.84	1.33	0.37	0.39	0.19	0.10	0.02	0.01	0.00	0.00	9.25
03-04	0.98	0.18	0.04	0.08	0.06	0.10	0.01	0.00	0.00	0.00	1.46
04-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	68.33	18.75	7.40	2.82	0.89	0.59	0.14	0.03	0.18	0.90	

Table 8

DADE COUNTY BETWEEN FILL AND DREDGE SITES

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC)										TOTAL
	<5-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	>22	
00-01	42.44	6.00	1.23	0.39	0.17	0.14	0.04	0.01	0.24	1.16	51.82
01-02	26.37	9.95	2.28	0.55	0.20	0.10	0.02	0.01	0.09	0.57	40.14
02-03	2.02	2.37	1.37	0.42	0.17	0.09	0.01	0.02	0.03	0.11	6.60
03-04	0.15	0.25	0.34	0.19	0.07	0.05	0.01	0.00	0.00	0.01	1.07
04-05	0.05	0.02	0.11	0.09	0.06	0.03	0.00	0.01	0.01	0.00	0.39
05-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	71.04	18.59	5.32	1.62	0.66	0.42	0.08	0.05	0.37	1.86	

Table 9

TREASURE ISLAND FILL SITE

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC)										TOTAL
	<5-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	>22	
00-01	39.77	5.07	0.76	0.21	0.09	0.04	0.09	0.11	0.25	1.44	47.83
01-02	17.96	8.71	2.64	0.40	0.05	0.20	0.09	0.00	0.09	0.69	30.82
02-03	9.16	5.59	3.61	1.90	0.42	0.32	0.04	0.00	0.05	0.27	21.35
03-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	66.89	19.37	7.01	2.51	0.56	0.56	0.22	0.11	0.39	2.39	

Table 10

PANAMA CITY BETWEEN FILL AND DREDGE SITES

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC)										TOTAL
	<5-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	>22	
00-01	51.50	2.43	0.32	0.22	0.18	0.00	0.00	0.43	0.45	0.97	56.49
01-02	24.54	5.65	1.78	0.30	0.11	0.00	0.00	0.10	0.08	0.26	32.82
02-03	1.85	3.74	1.27	0.30	0.06	0.11	0.00	0.00	0.00	0.15	7.48
03-04	0.00	1.46	0.17	0.48	0.00	0.07	0.00	0.00	0.00	0.03	2.20
04-05	0.00	0.42	0.31	0.28	0.00	0.00	0.00	0.00	0.00	0.00	1.01
05-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	77.89	13.69	3.86	1.58	0.35	0.18	0.00	0.53	0.53	1.40	

Table 11

REDONDO BEACH DEEP WATER

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC) <4-6	6-8	8-10	10-12	12-14	14-16	16-18	>18	TOTAL
0.0-0.5	1.55	11.48	2.57	1.62	28.08	18.47	4.79	0.66	69.17
0.5-1.0	11.07	2.88	1.08	0.66	4.31	4.03	1.27	0.09	25.89
1.0-1.5	2.21	1.61	0.15	0.02	0.01	0.00	0.08	0.00	4.08
1.5-2.0	0.02	0.40	0.02	0.01	0.01	0.00	0.00	0.00	0.45
2.0-2.5	0.00	0.14	0.11	0.00	0.00	0.00	0.00	0.00	0.25
2.5-3.0	0.00	0.02	0.04	0.00	0.00	0.00	0.00	0.00	0.06
3.0-3.5	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
TOTAL	14.85	16.58	3.07	2.30	32.33	22.50	6.14	0.76	

Table 12

REDONDO BEACH FILL SITE

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC)								TOTAL
	<4-6	6-8	8-10	10-12	12-14	14-16	16-18	>18	
0.0-0.5	3.10	11.80	2.59	1.66	28.50	19.04	4.81	0.54	72.04
0.5-1.0	10.09	3.05	1.11	0.62	4.44	3.47	1.26	0.19	24.23
1.0-1.5	1.65	1.29	0.12	0.01	0.01	0.00	0.07	0.03	3.18
1.5-2.0	0.01	0.31	0.06	0.01	0.01	0.00	0.00	0.00	0.40
2.0-2.5	0.00	0.07	0.08	0.00	0.00	0.00	0.00	0.00	0.15
2.5-3.0	0.00	0.00	0.01	0.00	0.00	0.00	0.00	0.00	0.01
3.0-3.5	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	14.85	16.53	3.97	2.30	32.95	22.50	6.14	0.76	

Table 13

INDIANA DUNES FILL SITE

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC)										TOTAL
	<5-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	>22	
00-01	39.06	2.54	0.51	0.12	0.00	0.00	0.00	0.00	0.00	0.00	42.23
01-02	30.40	3.70	1.53	0.36	0.06	0.00	0.00	0.00	0.00	0.00	36.05
02-03	4.78	9.32	4.22	2.38	0.39	0.36	0.18	0.09	0.00	0.00	21.72
03-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	74.24	15.56	6.26	2.86	0.45	0.36	0.18	0.09	0.00	0.00	

Table 14

PRESQUE ISLE DEEP WATER

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC)										TOTAL
	<5-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	>22	
00-01	47.91	1.07	0.21	0.09	0.04	0.00	0.00	0.00	0.25	0.13	49.70
01-02	35.63	3.88	0.98	0.38	0.08	0.00	0.00	0.00	0.00	0.09	41.05
02-03	4.22	2.05	0.73	0.34	0.04	0.00	0.00	0.00	0.00	0.00	7.38
03-04	0.64	0.81	0.21	0.04	0.00	0.00	0.00	0.00	0.00	0.00	1.70
04-05	0.00	0.04	0.04	0.00	0.04	0.04	0.00	0.00	0.00	0.00	0.17
05-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	88.41	7.84	2.17	0.85	0.21	0.04	0.00	0.00	0.25	0.21	

Table 15

PRESQUE ISLE FILL SITE

CUMULATIVE SEA / SWELL FREQUENCIES OF WAVE HEIGHT AND PERIOD

ANNUAL SUMMARY

HEIGHT (M)	PERIOD (SEC)										TOTAL
	<5-6	6-8	8-10	10-12	12-14	14-16	16-18	18-20	20-22	>22	
00-01	56.61	1.61	0.27	0.09	0.03	0.00	0.00	0.00	0.16	0.10	58.86
01-02	28.20	3.20	0.68	0.23	0.05	0.00	0.00	0.00	0.10	0.04	32.50
02-03	3.59	3.03	1.22	0.53	0.14	0.04	0.00	0.00	0.00	0.07	8.63
03-04	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
04-05	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
05-06	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
06-07	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
07-08	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
08-09	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
09-10	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
TOTAL	88.41	7.8[illegible]	2.17	0.85	0.21	0.04	0.00	0.00	0.25	0.21	

Table 16

Summary of Tables, Figures, and Appendixes

Project Site	Location and Bathymetry Figure No.	Annual Wave Height/Period Table No.	Annual Wave-Height Frequency Plate No.	Monthly and Directional Data Appendix No.
Revere Beach				
Dredge Site, Fill Site	2	3	1	B
Rockaway Beach				
Dredge Site, Fill Site	3	4	2	C
Carolina Beach	4			D
Dredge Site		5	3	
Fill Site		6	4	
Nassau County				
Dredge Site, Fill Site	5	7	5	E
Dade County				
Dredge Site, Fill Site	6	8	6	F
Treasure Island				
Dredge Site, Fill Site	7	9	7	G
Panama City				
Dredge Site, Fill Site	8	10	8	H
Redondo Beach	9			I
Dredge Site		11 (deep water)	9	
Fill Site		12	10	
Indiana Dunes				
Dredge Site, Fill Site	10	13	11	J
Presque Isle	11			K
Dredge Site		14 (deep water)	12	
Fill Site		15	13	

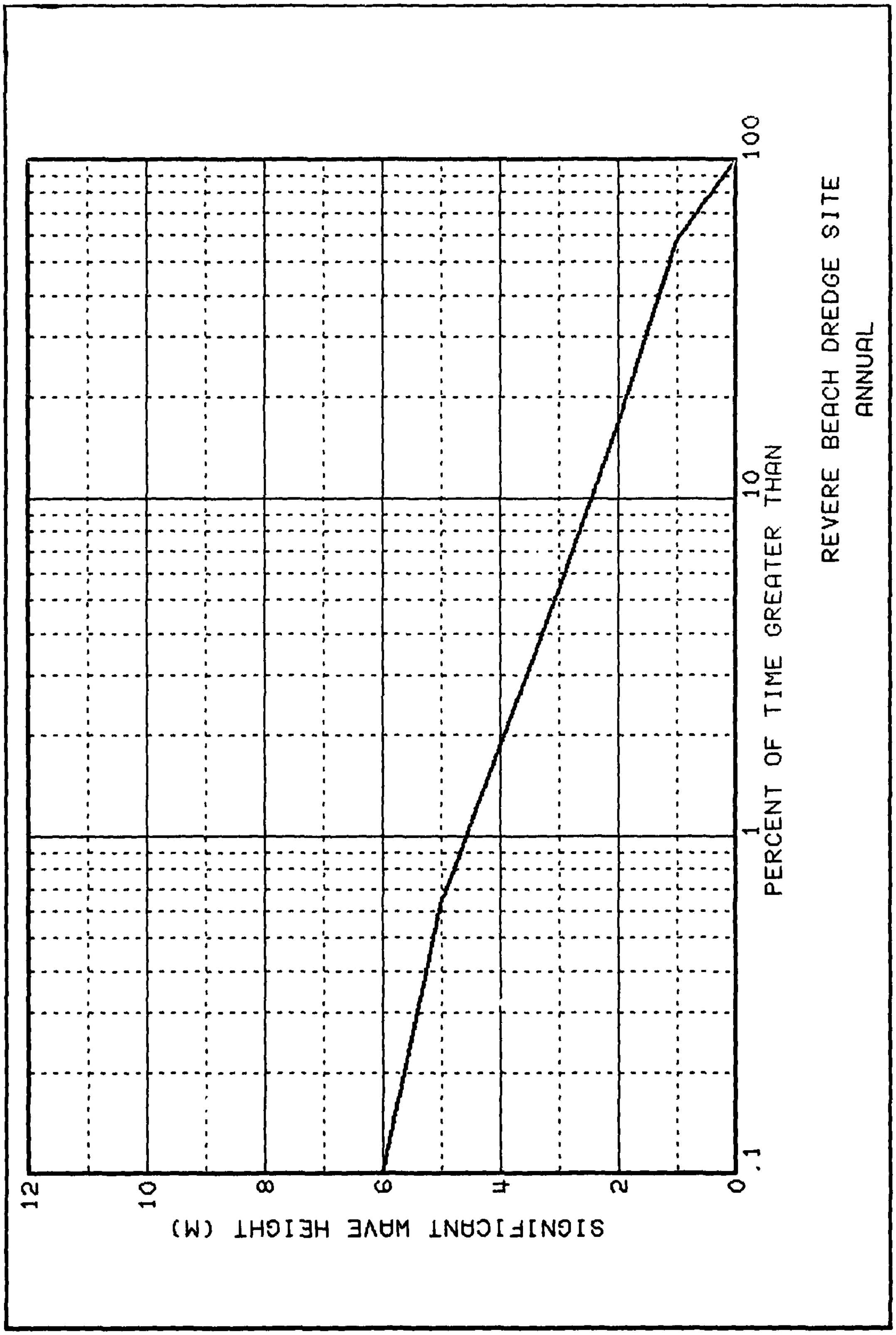
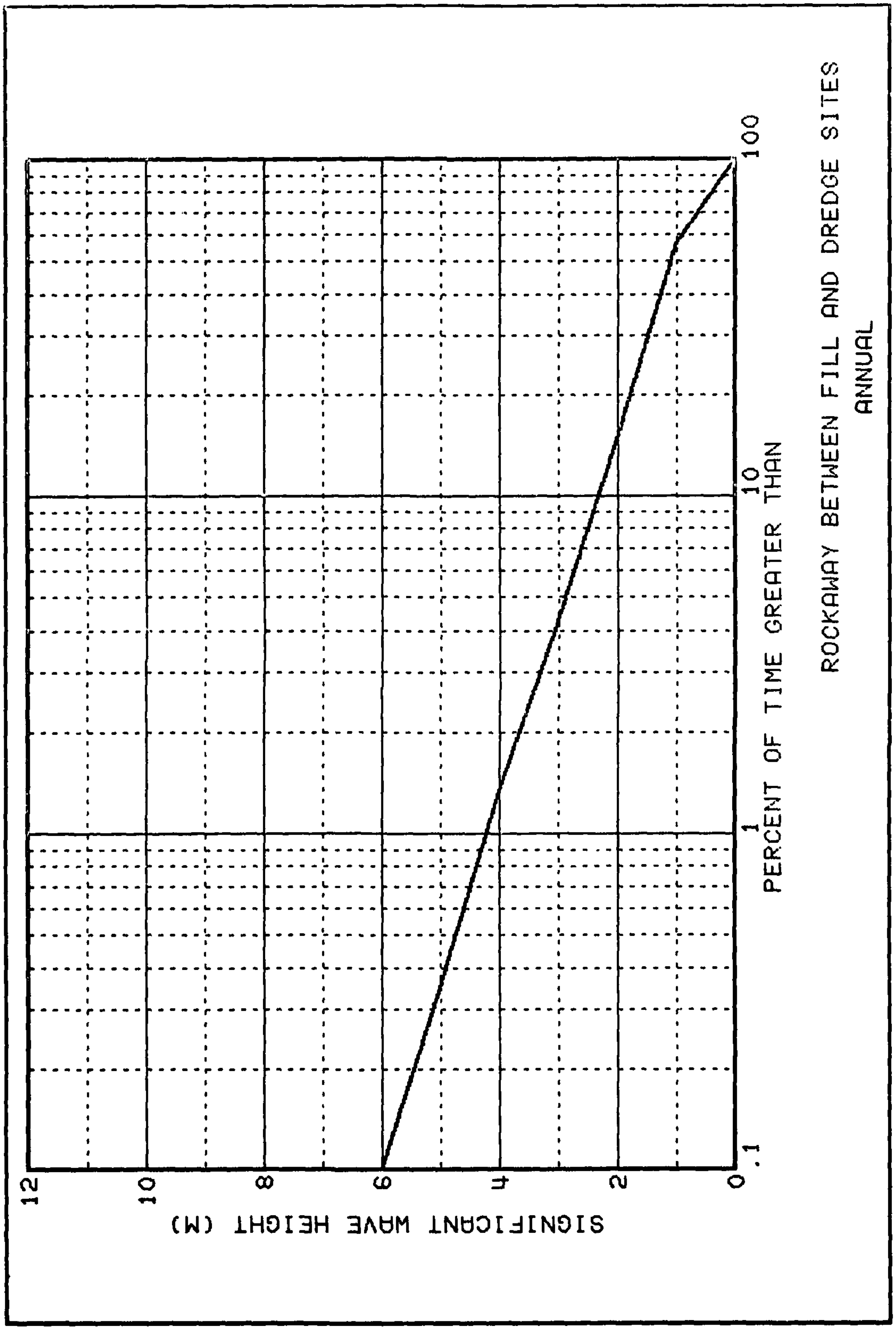
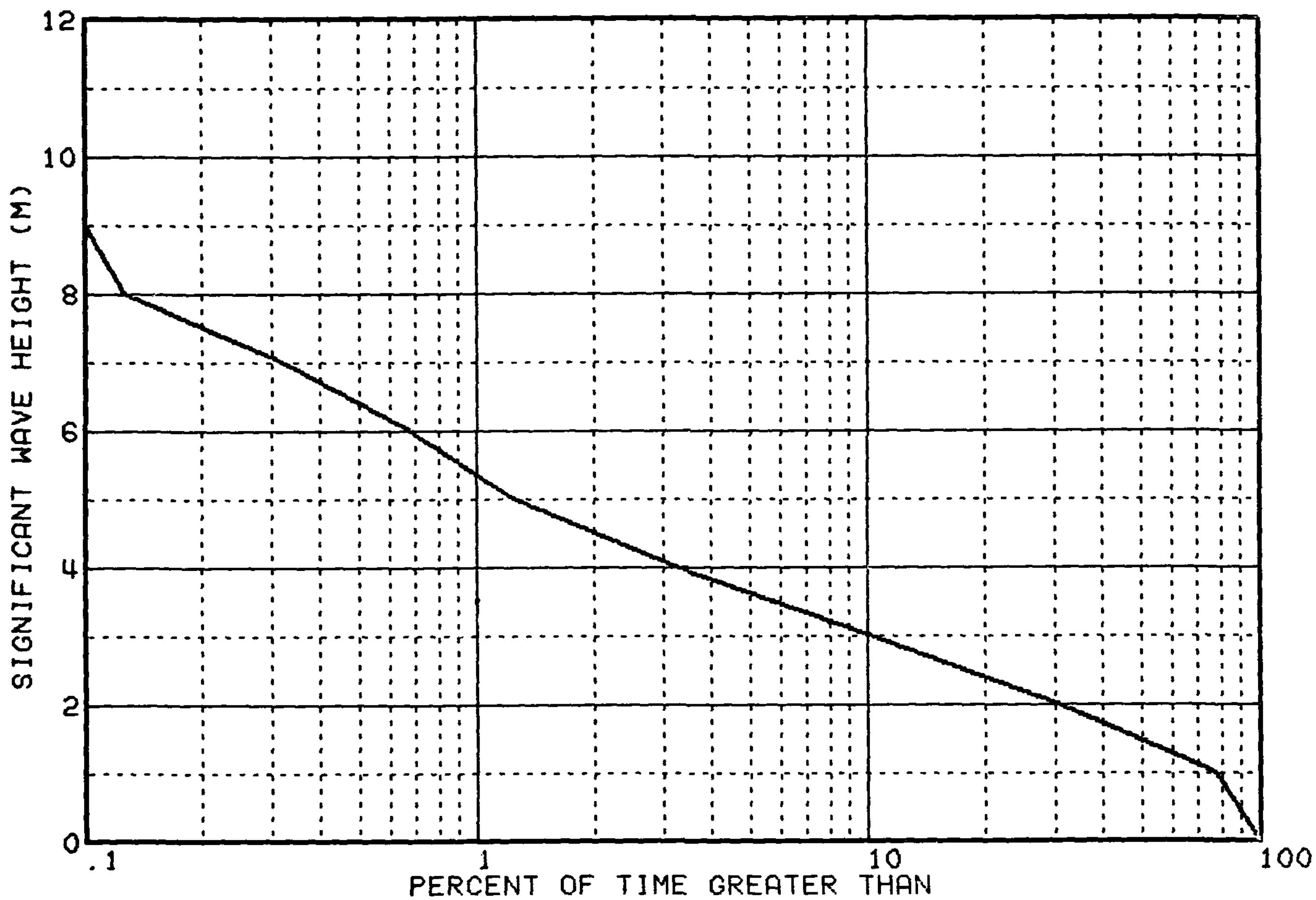

REVERE BEACH DREDGE SITE
ANNUAL
PERCENT OF TIME GREATER THAN
.1
1
10
100
SIGNIFICANT WAVE HEIGHT (M)
0
2
4
6
8
10
12

PLATE 1



ROCKAWAY BETWEEN FILL AND DREDGE SITES
ANNUAL
PERCENT OF TIME GREATER THAN
.1
1
10
100
SIGNIFICANT WAVE HEIGHT (M)
0
2
4
6
8
10
12

PLATE 2



CAROLINA BEACH DREDGE SITE
ANNUAL

PLATE 3

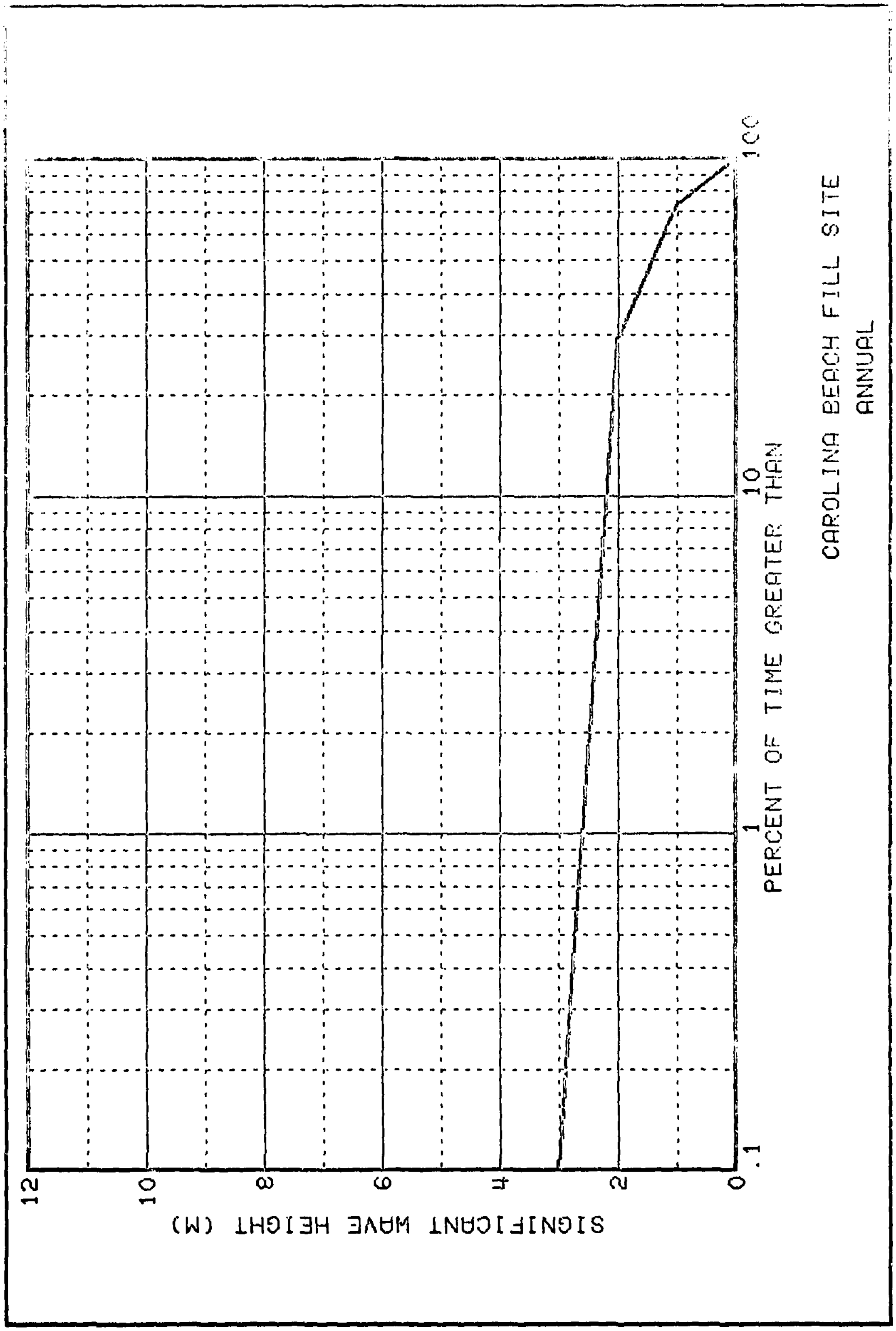

CAROLINA BEACH FILL SITE
ANNUAL
PERCENT OF TIME GREATER THAN
.1
1
10
100
SIGNIFICANT WAVE HEIGHT (M)
0
2
4
6
8
10
12

PLATE 4

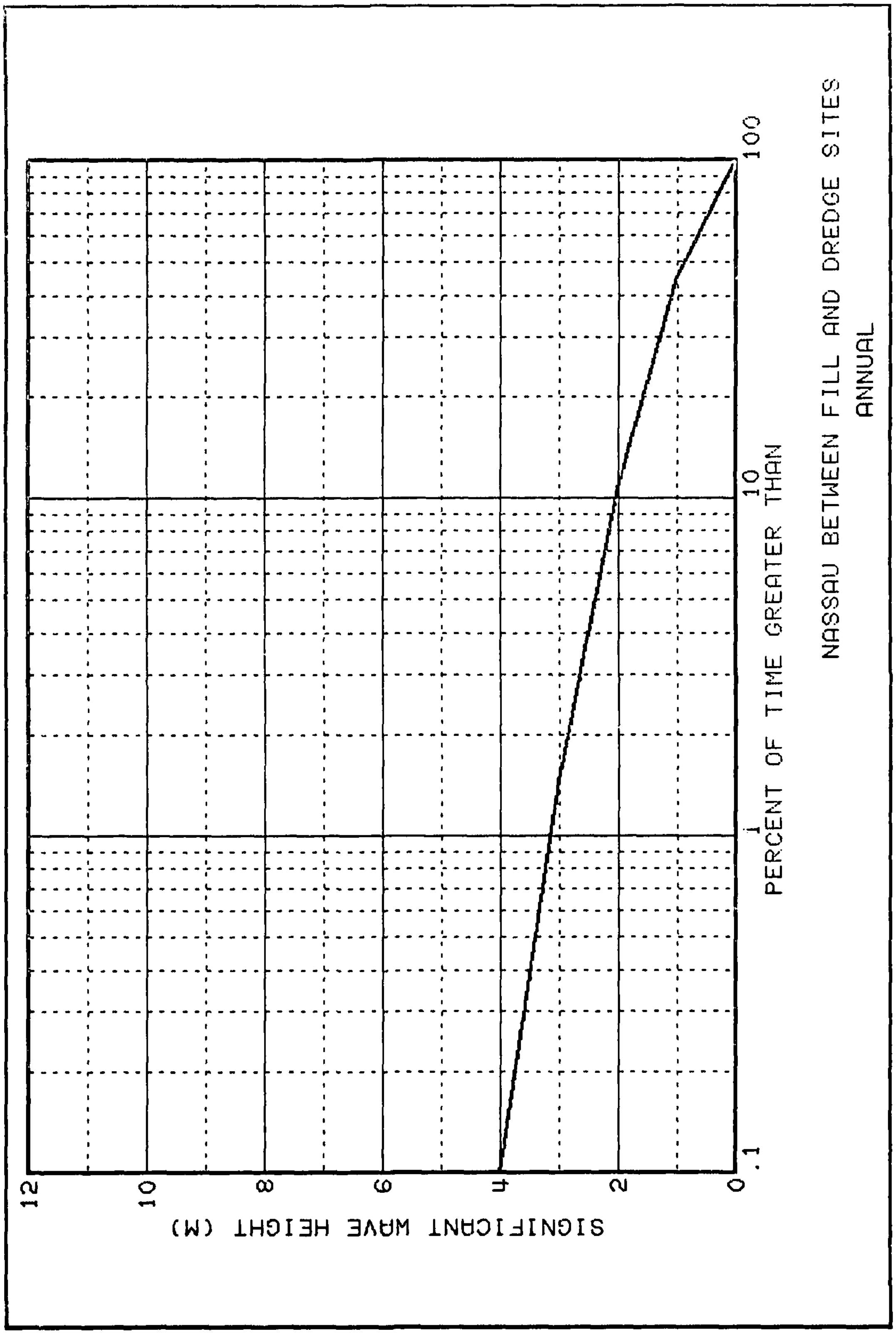

NASSAU BETWEEN FILL AND DREDGE SITES
ANNUAL
PERCENT OF TIME GREATER THAN
.1
1
10
100
SIGNIFICANT WAVE HEIGHT (M)
0
2
4
6
8
10
12

PLATE 5

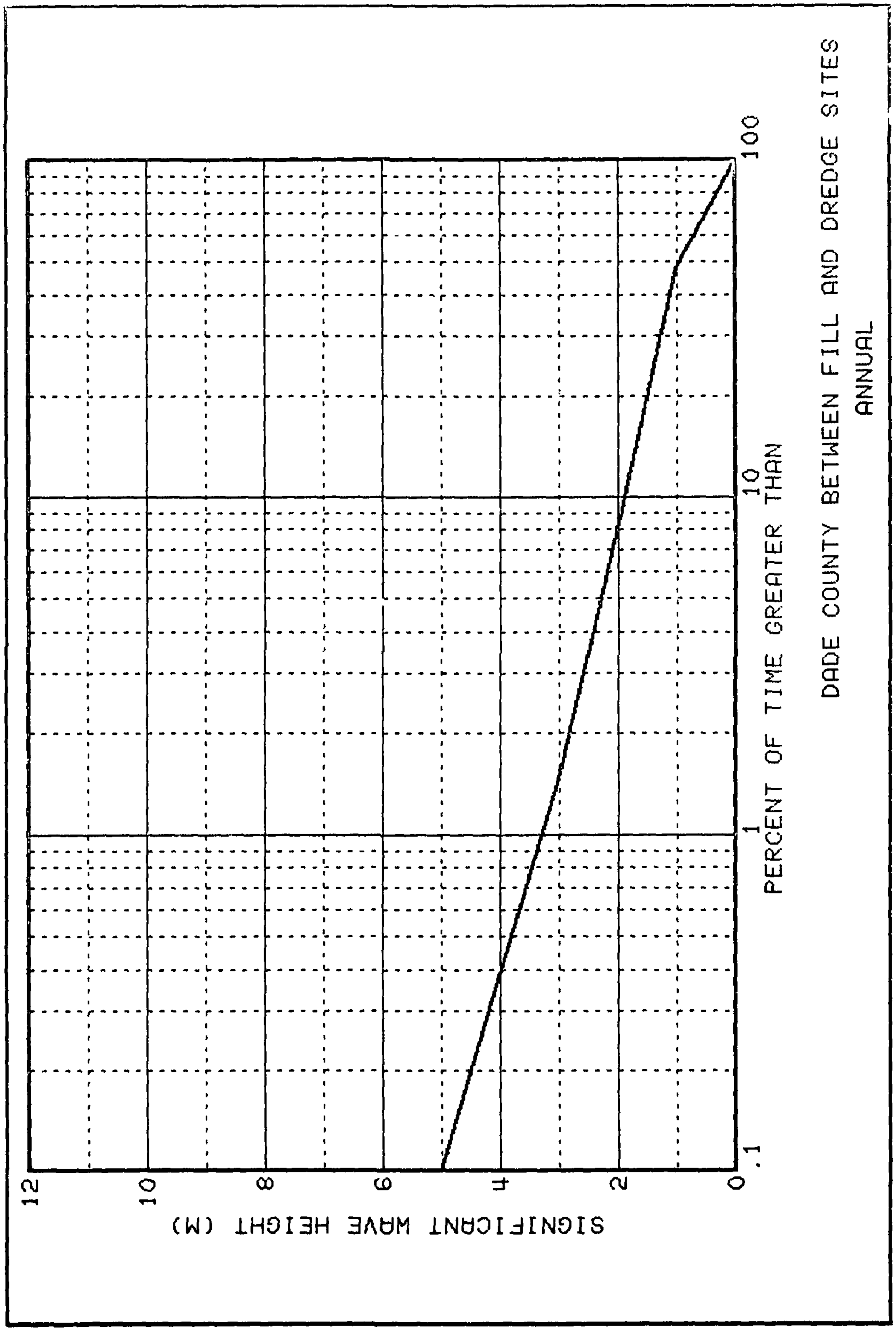

DADE COUNTY BETWEEN FILL AND DREDGE SITES
ANNUAL
PERCENT OF TIME GREATER THAN
.1
1
10
100
SIGNIFICANT WAVE HEIGHT (M)
0
2
4
6
8
10
12

PLATE 6

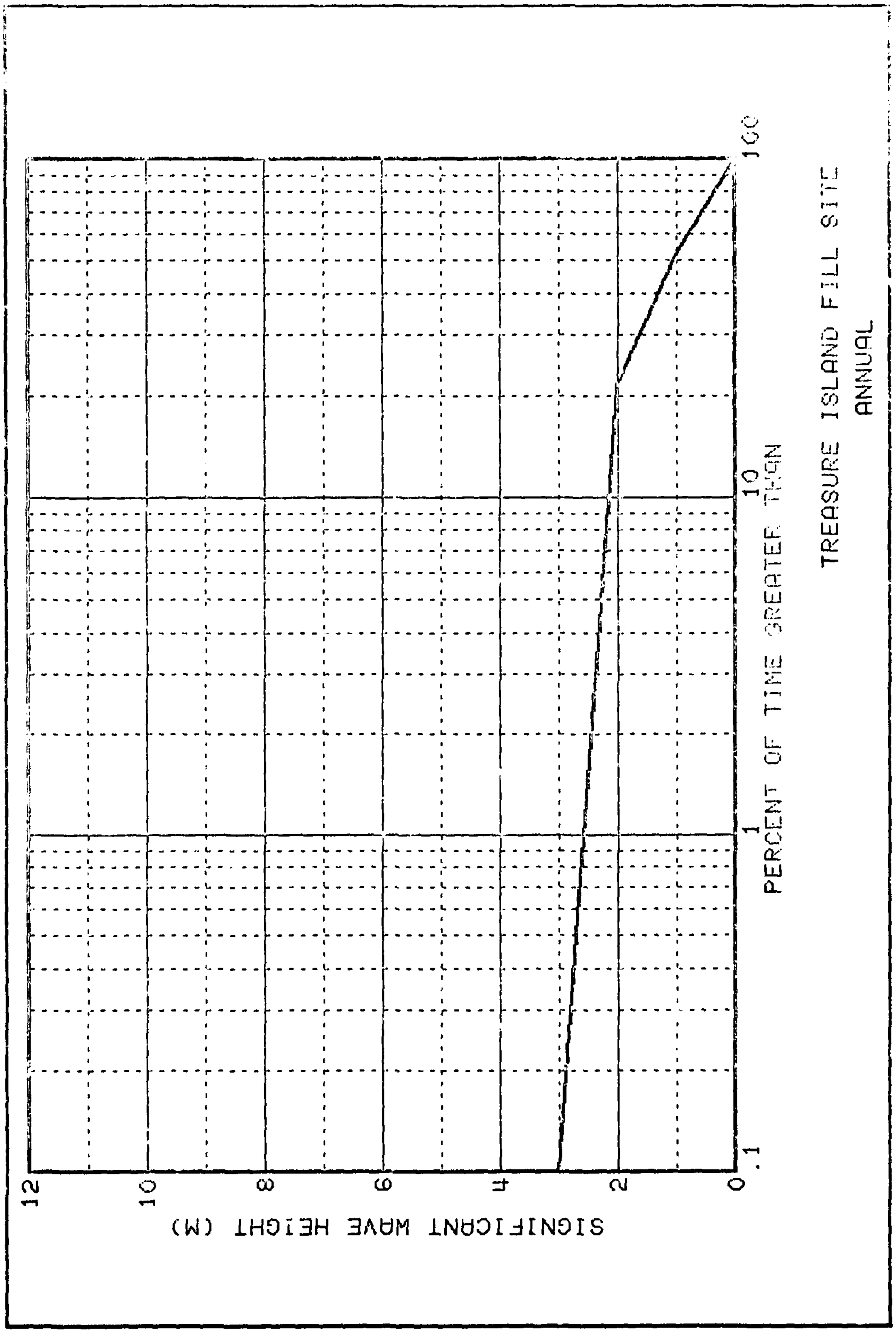

TREASURE ISLAND FILL SITE
ANNUAL
PERCENT OF TIME GREATER THAN
.1
1
10
100
SIGNIFICANT WAVE HEIGHT (M)
0
2
4
6
8
10
12

PLATE 7

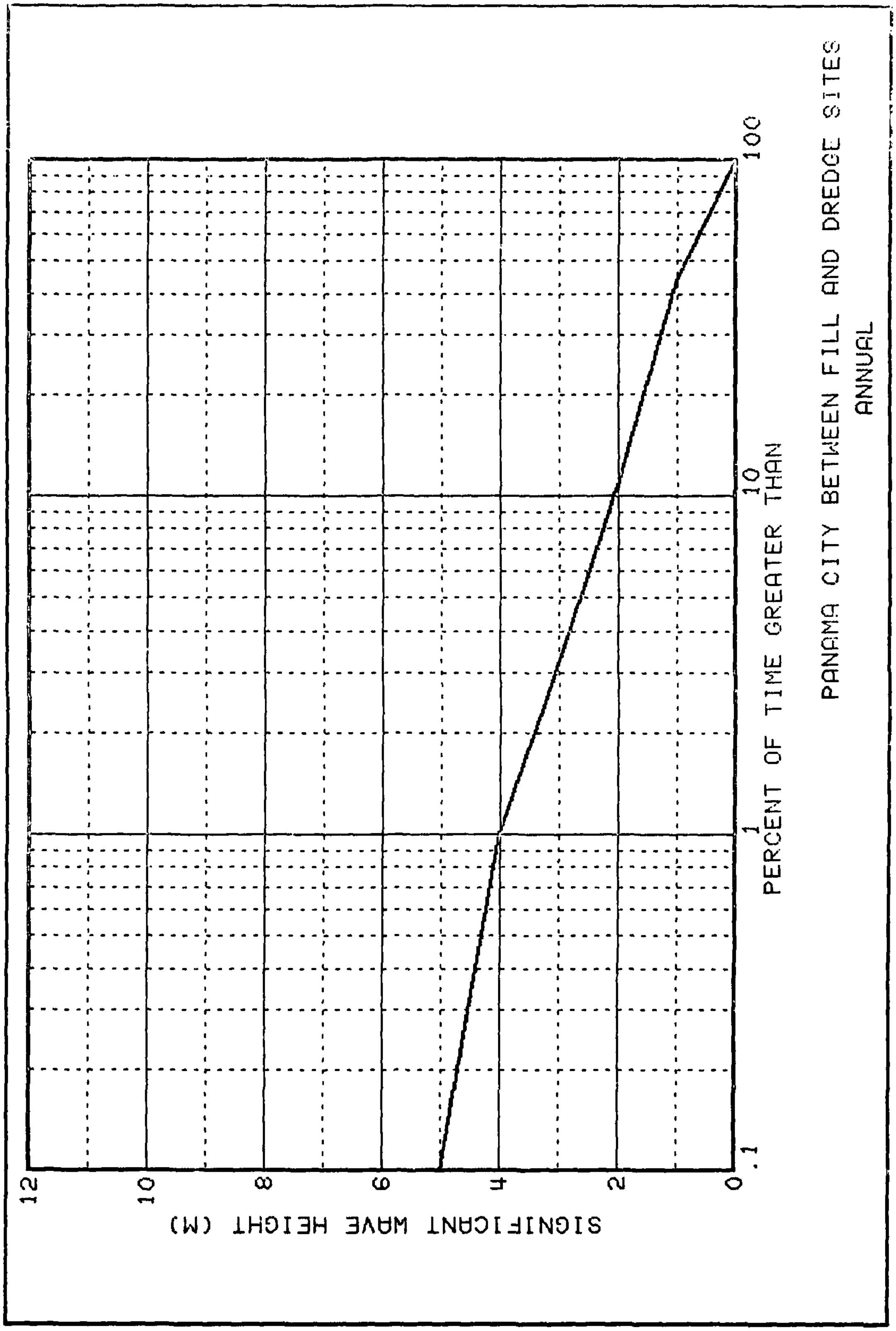

PANAMA CITY BETWEEN FILL AND DREDGE SITES
ANNUAL
PERCENT OF TIME GREATER THAN
.1
1
10
100
SIGNIFICANT WAVE HEIGHT (M)
0
2
4
6
8
10
12

PLATE 8

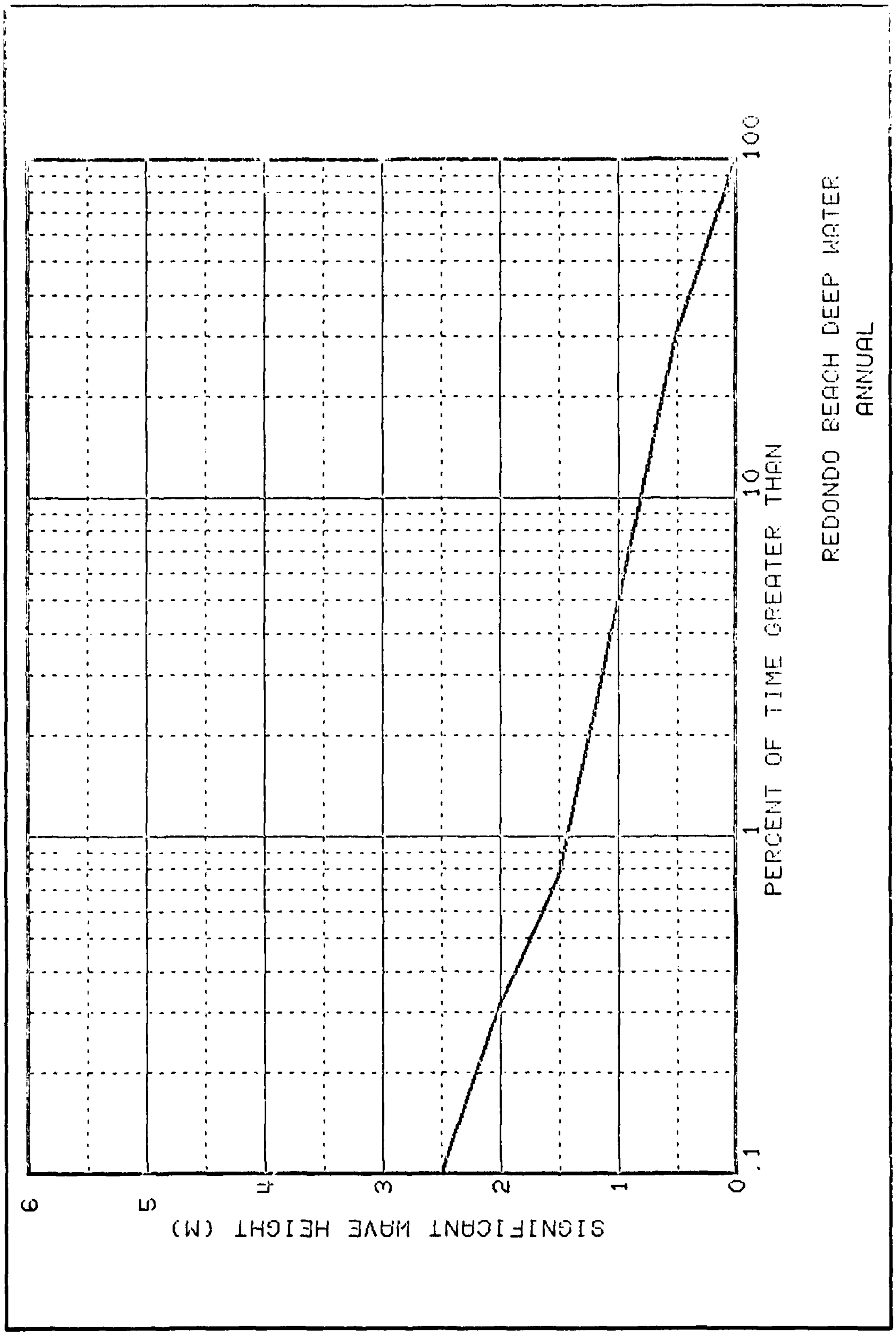
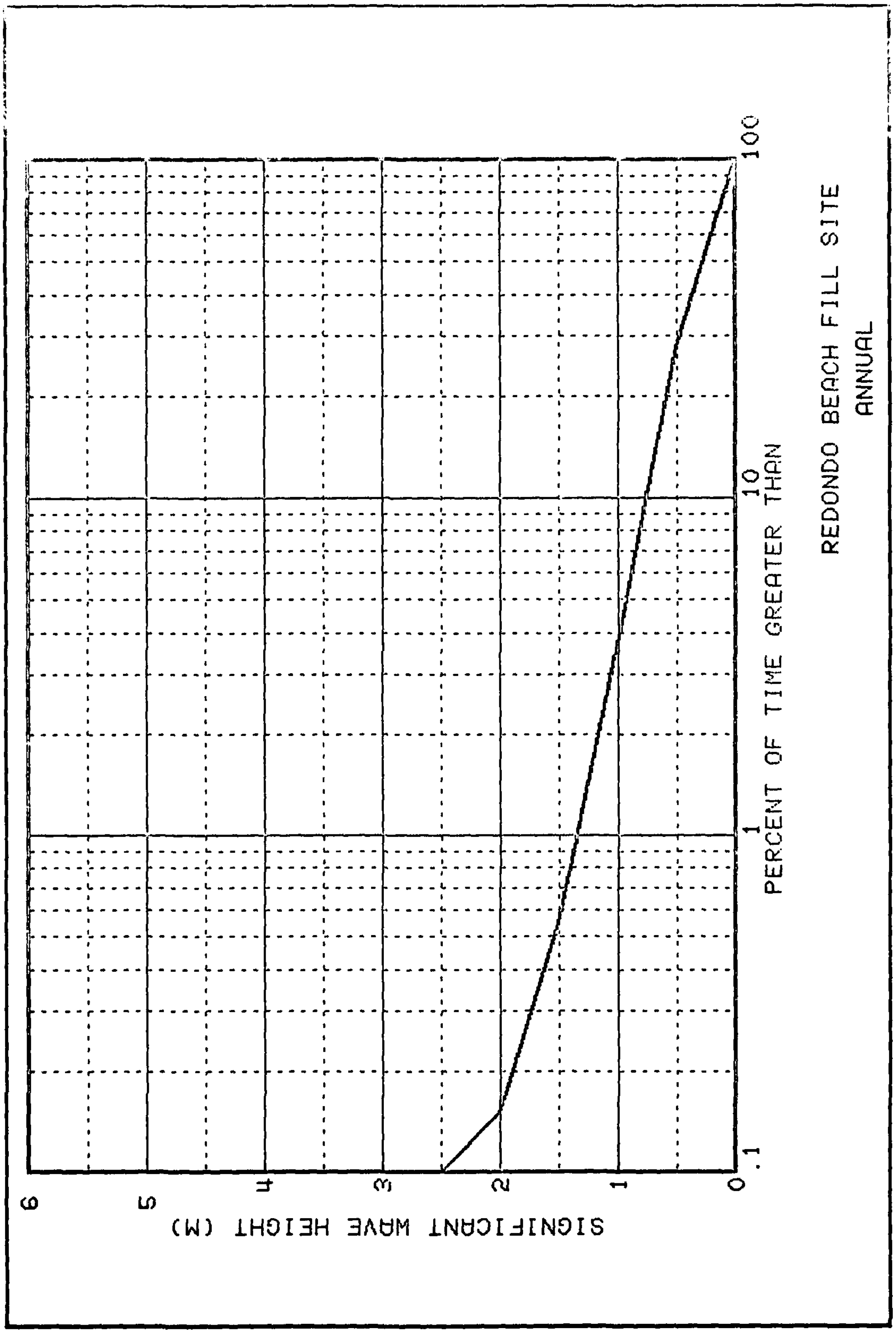

SIGNIFICANT WAVE HEIGHT (M)
0
1
2
3
4
5
6
.1
1
10
100
PERCENT OF TIME GREATER THAN
REDONDO BEACH DEEP WATER
ANNUAL

PLATE 9



REDONDO BEACH FILL SITE
ANNUAL
PERCENT OF TIME GREATER THAN
.1
1
10
100
SIGNIFICANT WAVE HEIGHT (M)
0
1
2
3
4
5
6

PLATE 10

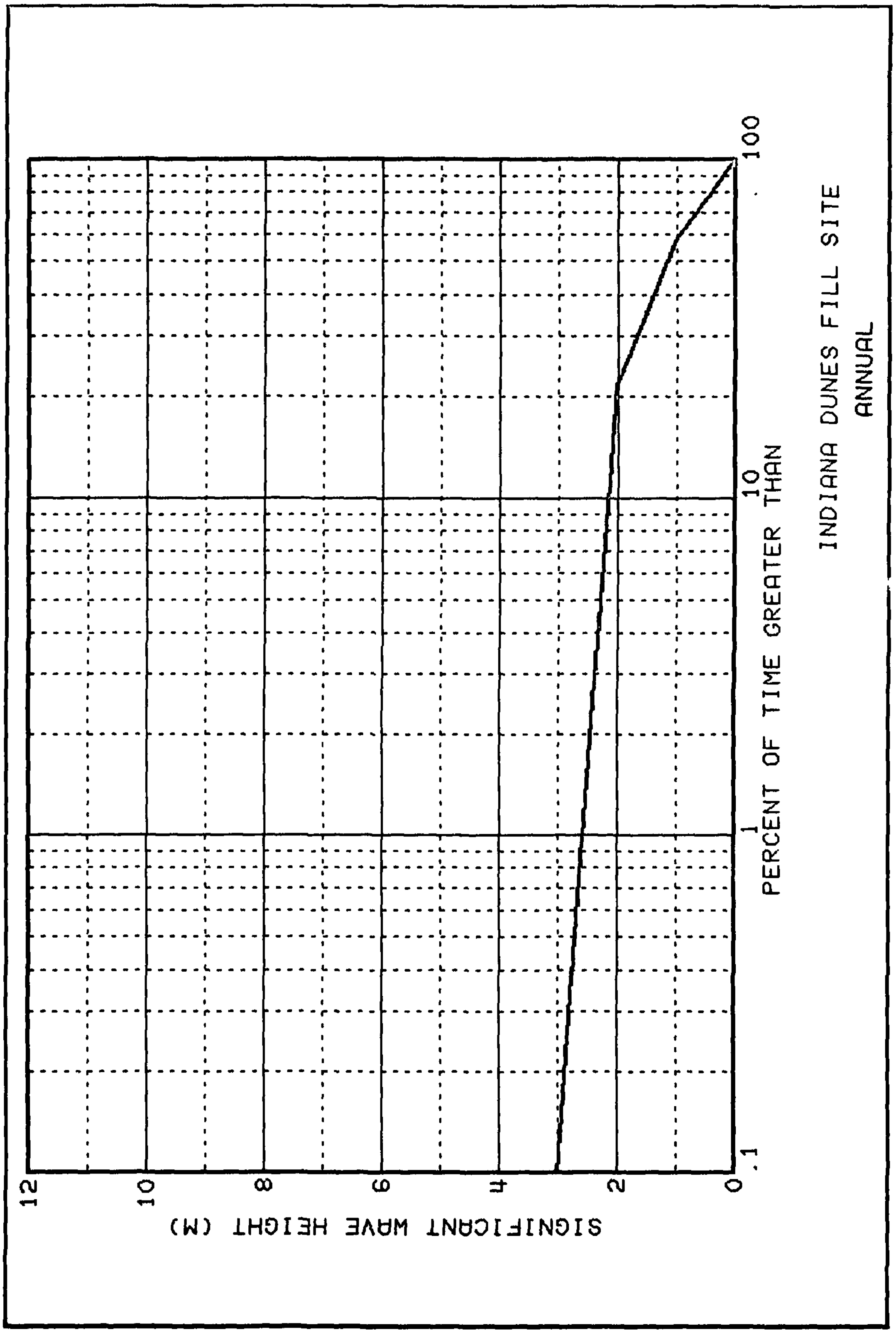

INDIANA DUNES FILL SITE
ANNUAL
PERCENT OF TIME GREATER THAN
.1
1
10
100
SIGNIFICANT WAVE HEIGHT (M)
0
2
4
6
8
10
12

PLATE 11

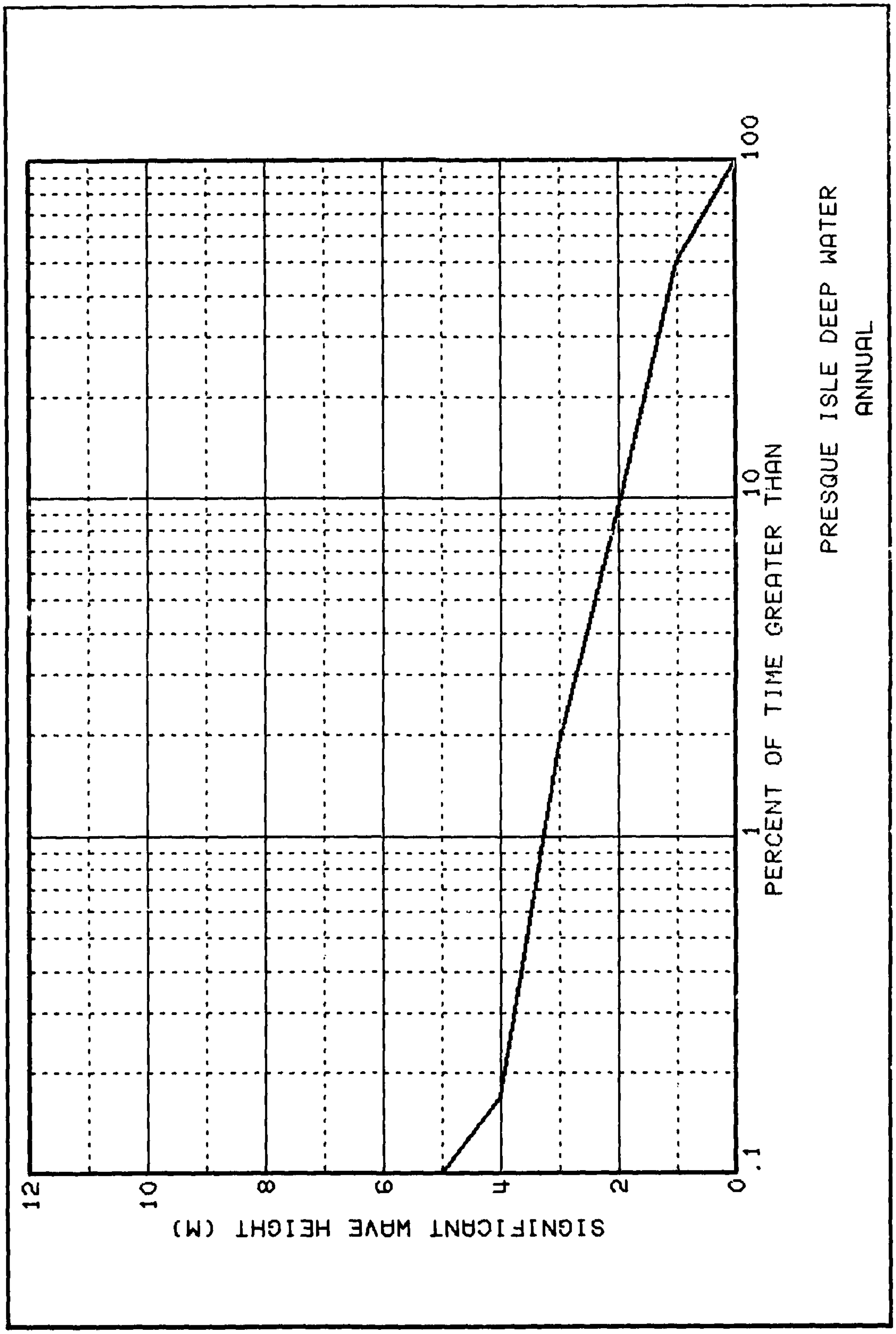

PRESQUE ISLE DEEP WATER
ANNUAL
PERCENT OF TIME GREATER THAN
.1
1
10
100
SIGNIFICANT WAVE HEIGHT (M)
0
2
4
6
8
10
12

PLATE 12

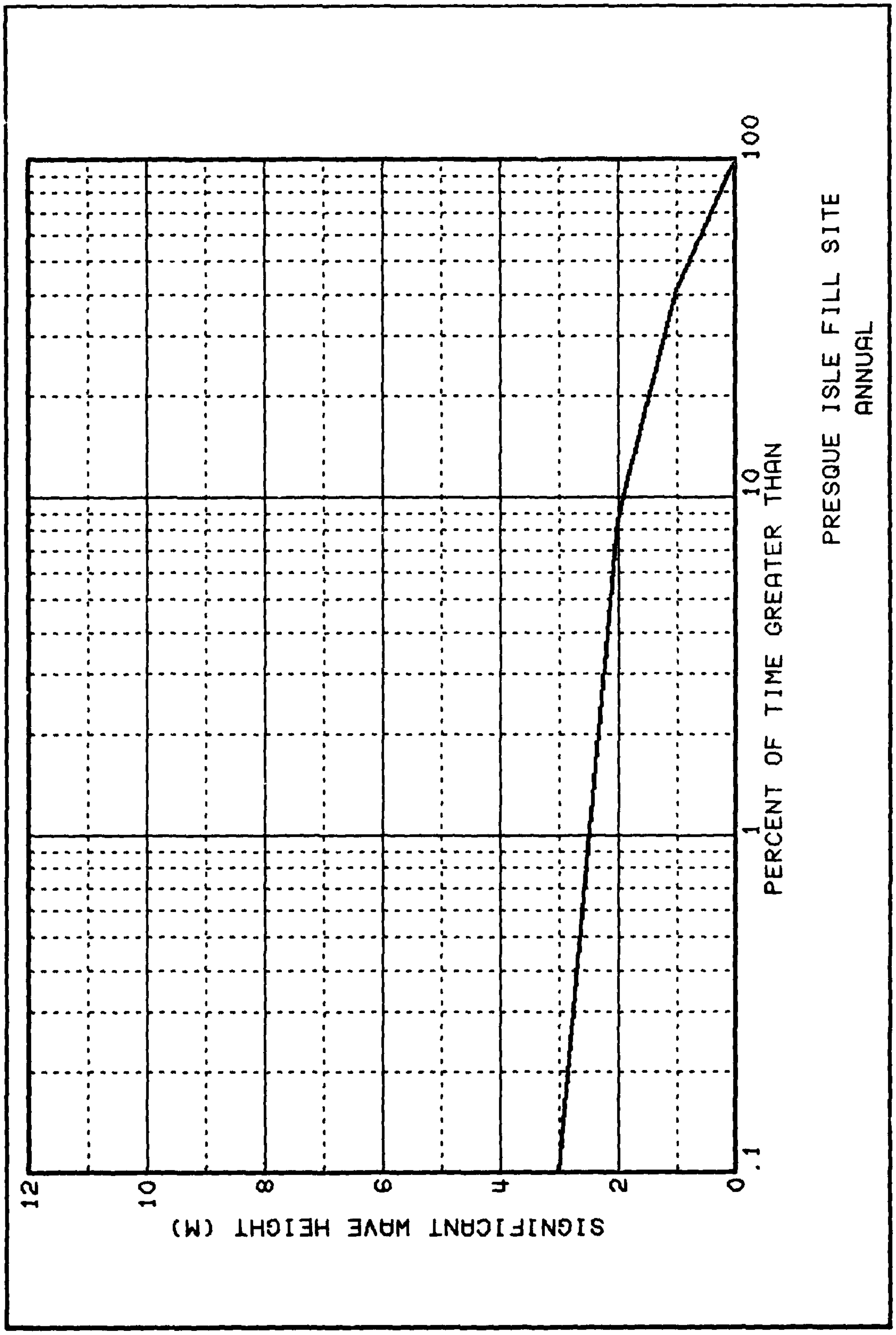

PRESQUE ISLE FILL SITE
ANNUAL
PERCENT OF TIME GREATER THAN
SIGNIFICANT WAVE HEIGHT (M)
.1
1
10
100
0
2
4
6
8
10
12

PLATE 13

In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Durham, Donald L.
  Beach nourishment techniques : Report 4 : Wave climates for selected U.S. Offshore Beach Nourishment Projects : Main text / by Donald L. Durham, Lyndell Z. Hales, Thomas W. Richardson (Hydraulics Laboratory, U.S. Army Engineer Waterways Experiment Station.) -- Vicksburg, Miss. : The Station, 1981.
  43, [16] p., 13 pages of plates : ill. ; 27 cm. -- (Technical report / U.S. Army Engineer Waterways Experiment Station ; H-76-13, Report 4.)
  Cover title.
  "Prepared for Office, Chief of Engineers, U.S. Army."
  "A limited number of copies of Appendixes A through K were published under separate cover. Copies are available from National Technical Information Service, Springfield, Va. 22161."

  1. Beach erosion. 2. Dredging. 3. Water waves. I. Hales, Lyndell S. II. Richardson, Thomas W. III. United States. Army. Corps of Engineers. Office

Durham, Donald L.
  Beach nourishment techniques : Report 4 : Wave : ... 1981.
(Card 2)

of the Chief of Engineers. IV. United States. Army Engineer Waterways Experiment Station. Hydraulics Laboratory. V. Title VI. Series: Technical report (United States. Army Engineer Waterways Experiment Station) ; H-76-13, Report 4.
TA7.W34 no.H-76-13 Report 4